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MAINTAINING AN ADEQUATE LEVEL OF GEOPHYSICAL EXPLORATION*

F. GOLDSTONE†

At the time of the Denver meeting last year, many geologists and geophysicists were frankly in doubt as to where their duty lay in the war effort. This year there should be much less uncertainty as we have been given a task on the home front which will tax our resources to the utmost. The task, to locate 4500 wildcat wells so judiciously that neither steel nor manpower will be wasted in unjustified drilling. The facts which seem to make necessary this enormous wildcat drilling program in the face of a national shortage of critical materials and manpower have been widely publicized in the trade journals, and I will only briefly recapitulate them.

In 1942 we consumed about 1385 million barrels of oil. P.A.W. statisticians tell us that in this same period and at a conservative estimate, we found 317 million barrels of new oil in new fields; on the most liberal estimating basis, including new horizons in old fields, they are willing to raise the figure to 801 million; one well informed trade journal estimates discoveries at 323 million barrels for new fields, and, finally, the A.P.I. places the figure at 260 million. Personally, I am inclined to accept the highest of these estimates, namely, 801 million barrels given by P.A.W., as being the most probable measure of oil found in new fields and horizons last year. However, such estimates of petroleum reserves made in the past have proved to be very inexact and subject to influence by the philosophical basis of the computations; furthermore, we are not justified in equating discoveries

* Presidential Address, delivered to a joint session of the Society of Exploration Geophysicists, the American Association of Petroleum Geologists, and the Society of Economic Paleontologists and Mineralogists, at Fort Worth, Texas, April 8, 1943.

† Shell Oil Company, Incorporated, Houston, Texas.

made during any one year with exploration during that year since there is a lag of from months to years between exploration and drilling. There is, therefore, plenty of room for differences in individual opinion and statisticians can so present the figures as to support widely different contentions. Probably the safest course is to study the trend of estimates made periodically on the same basis. Published estimates which extend back a number of years suggest that the yearly discovery rate of new oil in new fields has been declining for the past five years at least. It is a reasonable assertion that some time in the not distant past, consumption exceeded the finding rate of ultimately recoverable oil in new fields for the first time in our history as a major industry; whether this happened as recently as last year, or as long ago as 1939, is probably uncertain. What is more important, not only has the tide of discovery turned, but the ebb is now felt to be running very fast.

We are told that no prudent appraisal of the present reserve situation can tolerate a substantial decrease in available reserves, particularly in certain strategic localities, and that the additional oil which will become available by extensions to known pools is inadequate. Our mandate is to discover new fields, even at the expense of a program of wildcatting exceeding the lushest years, and it is one principal purpose of our annual meeting this year to lay plans for so doing.

What methods to use in locating the wildcats which will bring in these new pools is debatable. Dr. Lahee,[1] in his helpful annual compilation of comparative ratios of discovery by various methods, gives geophysics first place with geology a good second, and random wildcatting a very poor third. These ratings are on the basis of the number of successful wildcats located by various methods as against those which were dry. Were these statistics amplified and re-analyzed to disclose the barrels of oil discovered by the various methods, they would furnish a direct guide as to the best present course. Unfortunately, there does not seem to be a more recent study than that made by J. B. Eby,[2] which extends only through 1938. Statistics taken from Dr. Lahee's tabulation suggest that wildcatting without geological or geophysical guidance was relatively unsuccessful, in that during the past five years three times as many wells were drilled to discover each producer as was the case under technical guidance. If we go back a few more years and put our appraisal on the basis of barrels of oil

[1] Frederic H. Lahee, Bull. Amer. Assoc. Petrol. Geol., Vol. 26, No. 6, p. 977.

[2] Petroleum and Natural Gas Production, W.P.A. (National Research Project) Report No. E-10 July 1939, Statistical Appendix p. 337.

found per well drilled, not forgetting East Texas, Slaughter, and several other large low relief fields, then the wildcatter might, and I believe does, show up to much better advantage. Nevertheless, in planning an exploration program which must achieve a certain minimum objective with reasonable assurance of success, it would be foolhardy to count on the discovery of such reserves by promiscuous wildcatting since the outcome is so largely a matter of chance.

Therefore, it seems wise to plan our exploration program along more predictable lines which will virtually assure the attainment of the minimum objective, and yet not preclude the spectacular results which in the past have so frequently rewarded those willing to take the maximum chances. Geophysics offers the best means, in most areas, of reducing structural uncertainties and so should figure prominently in the program. Let us now consider the prospects of the geophysical branch of exploration being able to maintain its high contribution to successful wildcatting.

In the first place, it is pertinent to review geophysical operations during the past year, both as regards scale and geographical distribution. My figures show that throughout 1942 an average of 225 seismograph crews and 50 gravity crews operated. There was also an assortment of "doodle bugs" which we will ignore for the purpose of this discussion. By far the greater part of these exploration facilities was concentrated in venerable areas of proven production. The backwoods of the presently unproductive areas attracted little exploration.

Thus, with what approaches an all-time high in scale of operation and a geographic and philosophic distribution of effort closely paralleling that followed in previous more successful years, we failed to achieve our goal of balancing discoveries against withdrawals; failed miserably by most figures, and failed badly even if the year's results are most optimistically appraised. This picture is made darker by the generally accepted belief that our backlog of good untested structural prospects in recognized oil territory is being rapidly exhausted.

To meet the present emergency there are four general ways in which we might utilize our geophysical exploration facilities.

In the first place, we could apply our existing techniques with even greater microscopic precision in the already well explored "golden lanes" of productive territory. Continual improvement in seismic methods has resulted in our ability to map accurately, at a cost, the smallest geological features which offer promise of being commercial structural type accumulations; so much of our effort has been directed

along this avenue that the natural result is now evident in the statistics—an increased number of discoveries is being made but the size of each individual field is small. We have such wide experience and complete statistics in operations of this type that the results of a further program can be estimated in advance, even to the point of hazarding a guess as to the cost of each barrel of oil *in situ* which will be found by such methods: including the cost of leases and exploratory dry holes, the figure will fall not far from thirty cents per barrel on a steeply rising curve. The law of diminishing returns has overtaken this "gleaning" phase in mature producing areas, and it is to be hoped that our imagination is not so atrophied or our resources so exhausted that we will long be satisfied with it. However, if the necessary facilities are available, and we have to meet a comparatively small objective of discovery, the method has the virtue of furnishing predictable results.

In the second place, we could take our proven methods of structural mapping to new territories as yet inadequately explored, either as regards their structure or stratigraphy. In operations of this type we must take the chance of finding that sediments now pronounced as lacking source beds or porosity, or both, turn up a Yates or a Tinsley. We cannot hope to estimate in advance a profitability factor—we may even be totally unsuccessful, but at least in this approach we are playing for high stakes in the best traditions in the industry we serve. The symposium to be conducted by the A.A.P.G. as a part of this program should bring to our attention many such areas.

As a third course, we can again match our technical abilities against the unsolved problems of the geophysically "tough" areas where extensive wildcatting only awaits adequate structural guidance. The problems to be faced in these areas are largely superficial, occasioned by a surface outcrop of limestone, the presence of caliche, or of thick gravel deposits. Southern Mississippi, a notoriously recalcitrant area, does not qualify under any of these descriptions, and presents an interesting problem which has not yet been completely solved. Such areas have been largely avoided as long as others offering greater ease of mapping remained partially unexplored; as the more easily mapped territories are exhausted, the incentive grows to direct effort to the more difficult. The challenge presented by the "tough" areas has been taken up and I believe the technical resources of the industry are such that, in most such areas, the outcome is not in doubt.

And, fourthly, we can look to new methods to revitalize explora-

tion. The history of geophysical exploration is a succession of surges in activity as new methods or techniques found favor, and each surge initiated a new bulge in the discovery rates. In my opinion, there is no prospect of a powerful new method being brought to immediate commercial success, and I am convinced that the present emergency must be met with the conventional tools already familiar to us, correctly applied, however, in the proper places; we would be foolish indeed to look to any new methods now visible on the horizon to solve our urgent problems for us the easy way.

No conceivable policy of exploration can, with a lesser effort than was made in 1942, offer reasonable assurance of maintaining the discovery rate of new oil. Of course, we might be the beneficiary of a windfall such as a second East Texas, and spectacular results might reward pioneering in new territory, but we cannot allow our reserves of petroleum, the most critical of all war materials, to be dependent entirely upon the outcome of any such gamble. It is my belief that to meet the immediate emergency we should persevere in the humdrum mapping of small structures in proven areas with the greater part of our available facilities. Nevertheless, it is to be earnestly hoped that enough facilities will remain to make possible a much expanded program in outstepping and poorly explored areas, as only in this way, I believe, can the creeping paralysis which has beset discovery be stayed. Furthermore, we have the Petroleum Administrator's announced objective of 4500 wildcat wells this year to face. If this objective is to be even approached, a high discovery rate of new prospects must be maintained as the backlog is on the way to exhaustion. Even so, many wells must be drilled to test prospects other than conventional closed structural traps in present productive areas; in the oil country there are nowhere near that number of structural prospects known and untested. Such an abundance of wildcats, if it proves economically possible to drill them, should insure the testing of virtually all our structural prospects and of many stratigraphic traps and yet leave enough over to follow up exploration in new areas.

Nothing in the present situation justifies a belief that the contribution of geophysical oil can be maintained with less facilities than we had last year; what are the chances of our keeping these facilities intact?

Our success in keeping a full complement of crews in the field during 1942 despite the drain of personnel to the army and war industry may have created a feeling of false security concerning our ability to

continue doing so. Dr. Weatherby, Chairman of the War Efforts Advisory Committee of the Society of Exploration Geophysicists, has assembled and analyzed figures bearing on the loss of personnel by geophysical operators, and I am indebted to him for most of the statistics used in this discussion. The total number of technically trained men employed in geophysics is not more than 2000 and the total complement of men, skilled and semi-skilled, in the industry does not exceed 5000. Of our technically trained staff, 40 per cent has been lost to the armed forces and to war work. Only the farsighted policy which had maintained technical men two deep in nearly all key posts throughout our pre-war organizations permitted the continuation of operations on the former scale despite this loss of men. We are now down to the first string team with virtually no reserves, and further losses of technical men will inevitably mean the shutting down of field crews. The seriousness of this situation cannot be exaggerated since a complete shutdown of seismograph exploration could be brought about by the removal of some 500 men. The position as regards semi-skilled workers is even worse. Statistics which cover over 80% of geophysical operations for 1942 disclose that 1428 men out of a total payroll of 4370 went into the services and 1974 into other industries—during the same period, 3252 replacements were hired, representing a turnover of 75%. In such a highly specialized type of operations, efficiency has naturally suffered; furthermore, the trend of the times may be indicated by the fact that at least four operators have already reduced the number of their crews in the field.

Second only in importance to manpower is the problem of obtaining the supplies we need. A study of the consumption of critical materials in our operations is illuminating. Our total consumption of dynamite for 1942 was about 5000 tons, which represents somewhat over 2% of the industrial consumption of the U.S.A. The manufacturers assure us that this comparatively small consumption has no effect on production for war, which is carried on in separate plants and involves a different type of product. Our consumption of steel is even more relatively insignificant. Shot hole casing is the largest single item, and, according to my own estimate, it amounted only to some 10,000 tons last year, of which most comprised discarded material of a type not in demand as scrap. Transportation probably constitutes our greatest drain on critical materials. The geophysical industry is operating some 2000 motor vehicles under unusually severe service conditions, and it is very difficult to see how we could substantially reduce this number.

It is the consensus of opinion among geophysical operators that the loss of trained personnel is our most serious problem. The particular type of training common in the ranks of geophysical organizations finds ready acceptance in many technical branches of the armed forces and also in war industry and research. Our ranks have been subjected to assaults from all these quarters and casualties have been high. To offset losses we have replaced men with women to the limited extent which the nature of field work makes proper; we have lengthened hours of work in the field, not only to the maximum of 48 adopted in most understaffed industries, but in most instances to 50, and in some, to 60 hours per week. We have attempted, within the limits imposed by the War Labor Board rulings, to raise the earnings of our personnel to bring them at least within sight of what these same men could earn in other industries.

In times such as these when critical materials and manpower must be doled out with a thrifty eye to the many urgent war demands, we can hardly expect to have our every request granted. We can, and must, assemble the facts which govern our ability to support our part of the war effort and bring these facts home to those who control the over-all effort. If, having before them these facts accurately assembled and realistically interpreted, the War Manpower Commission and the War Production Board decide that a proportion of our facilities must be diverted and exploration curtailed, then, and only then, should we feel free to follow our impulse to get into work more spectacularly contributing to the war effort. The job assigned to us is one which nobody else can do, and I believe we should take every possible step to keep our facilities for executing this job unimpaired; we should not hesitate to make the strongest possible representation to our fellow workers in the industry and also to Draft Boards and other agencies in an endeavor to hold exploration staffs intact; far from being unpatriotic, I believe this is the most realistic contribution which we, as individuals or as professional societies, can make to the war effort.

CONFERENCE—MAINTAINING GEOPHYSICAL OPERATIONS DURING THE WAR

REPORT OF THE WAR EFFORTS ADVISORY COMMITTEE*

B. B. WEATHERBY†

Members of the committee were widely scattered geographically and since several of them have been devoting a substantial part of their time to war work they were unavailable for meetings. Consequently most of the work has been carried on by the Chairman with the very able assistance of the President of the S. E. G., Mr. Goldstone, with whom numerous conferences have been held. I wish to apologize to all members for not having consulted them more frequently and I also wish to relieve them of any responsibility in connection with the activities of the committee. That responsibility is mine.

The first and only regular meeting occurred on June 12, 1942, at which time a thorough discussion was held on the means of serving both the interests of the Society and of the nation to the greatest advantage.

It was decided that in the case of bona fide and important needs of the government for the services of technical personnel the committee would get in touch with the heads of geophysical organizations to see if any men were available with the necessary qualifications. However, it was clearly understood that the committee would attempt to protect our personnel from general requests.

Society members were invited to direct communications to the Chairman or to any other committee member in connection with personal problems arising out of a desire for more direct participation in the war effort. A substantial number of such inquiries have been received and answered.

* This paper and the five which follow were presented at a conference on maintaining geophysical operations during the war which was held in Fort Worth, Texas, April 7, 1943.

† Geophysical Research Corporation and Amerada Petroleum Corporation, Tulsa, Oklahoma. The War Efforts Advisory Committee of the Society of Exploration Geophysicists consists of Dr. Weatherby, Chairman, and Messrs Henry C. Cortez, R. D. Wyckoff, Herbert Hoover, Jr., W. G. Green, and F. Goldstone.

It was further decided to circularize the geophysical organizations for the purpose of finding out what research, development and production facilities were available for war work. Questionnaires were sent out to 34 companies and 24 were returned. These indicated that on last September 1, there were 13 companies having interest in further work of this nature. Since that date, however, quite an inroad has been made on the available facilities. Great credit should be given Mr. Goldstone for his part in bringing substantial projects to our group. At the present time there are probably no appreciable untapped reservoirs of either production or development facilities. Recently a survey was made to see if a group of companies in the Tulsa area would be able to handle one fair sized project jointly. It turned out that this could not be done since virtually all machines and manpower were booked to capacity.

During a trip to Washington in September the facilities which were then available were called to the attention of the Naval Bureau of Aeronautics as well as to other branches of the Navy. Several contacts were also made with various sections of the National Defense Research Committee for the same purpose. It is probable that these efforts resulted in additional work coming our way.

During this stay in Washington it was my privilege to have a long conversation with General Hotchkiss, Deputy Director of the Army Specialist Corps, who explained quite fully the function of that organization. He indicated that this setup was not accomplishing its objective because of the unwillingness of the Army to requisition men from this source, but he expected a marked improvement in the near future. With this in mind questionnaires and a copy of one of General Hotchkiss' speeches were sent to the heads of each geophysical organization, since the Army Specialist Corps appeared to be an excellent stepping stone for those of our men who felt it necessary to become more directly associated with the war effort. Unfortunately, word was received in November that the Corps had been abolished and that its functions had been taken over by the Army Procurement Service.

During the American Petroleum Institute meetings in Chicago in November an effort was made to lay the groundwork for some statement from the O.P.C. to the effect that men engaged in exploration were playing a vital part in the war. Such a statement would have been very useful in convincing our personnel that they should not leave the important work in which they were presently engaged and

for which they were well qualified in order to volunteer for some branch of the Army or Navy or for some other type of employment where their value to the war effort would be less. However, up to the present time, no such statement has been issued, although it is now quite obvious that the P.A.W. is entirely sympathetic to such a point of view.

Early this year the committee seriously considered whether it should interest itself in the possibility of improving the materiel situation but decided that the priorities granted to exploration were all that could be expected. It was fully recognized that there was a substantial amount of delaying red tape but it was felt that this was no more than could be expected under the circumstances. At about this time Mr. Heroy, Director of Reserves of the P.A.W., took on the problem of assisting exploration units with their materiel difficulties and to that end sent out a short questionnaire asking for our requirements of essential raw material and fabricated articles.

At the January production committee meeting of the Petroleum Industry War Council in Washington it was pointed out that the serious personnel situation that had been developing, particularly in exploration, had not been sufficiently emphasized. Meanwhile the production committee had been busily engaged, first on obtaining a price increase which would accomplish the triple objective of stimulating exploration, furthering the use of secondary recovery methods, and prolonging the life of stripper wells; and, second, on the maintenance of an adequate flow of materials. However, a three-legged stool cannot stand without all its legs and it is a bit difficult to tell which is the most important. Thus, while the price leg and the material leg were being strengthened the personnel leg was being sawed off and the stool was getting wobbly.

At this meeting the production committee recommended to the P.I.W.C. that a manpower committee be appointed for the council. The recommendation was accepted and Mr. John Lovejoy was appointed head of this newly formed committee.

Shortly thereafter the War Efforts Advisory Committee decided that it could quite properly attempt to obtain some relief from our acute personnel situation and to that end questionnaires were sent out to 28 companies. The response was excellent and a very clear picture was obtained on the seriousness of the situation. These questionnaires were tabulated and made the subject of the following letter to Mr. Lovejoy:

February 26, 1943

Mr. John M. Lovejoy,
Chairman of Manpower Committee,
Petroleum Industry War Council,
Washington, D. C.

Dear Mr. Lovejoy:

As Chairman of the War Efforts Advisory Committee of the Society of Exploration Geophysicists, and as a member of the National Service Committee of the American Association of Petroleum Geologists, I have been listening for some time to reports on the seriousness of the personnel situation in the exploration field. Recent comments have shown that the problem has become very acute and some action must be taken if a sharp decline in activity is to be averted. In order to arrive at the facts of the case, questionnaires were sent to 28 geophysical companies or departments of companies representing 90% of all geophysical activity. Twenty-one replies were received covering 77% of the total volume of work being done. Consequently the combined experience of this group may be fairly taken as indicative of the situation in the whole industry.

These facts are summarized in the attached table. The information speaks for itself. In an activity carried on by 4400 men on January 1, 1942, there were less than 4100 on January 1, 1943, even though better than 2900 were hired during the year. In the face of this drastic turnover and drop in total number of men employed there were five more parties in the field at the year end. The above figures show that there was an average loss of two men per party, but what is far more important there was a great decrease in the skill and efficiency of the personnel caused by the lack of experience of the men hired during the year.

Sixteen of the twenty-one companies state that there was no decrease in the rate of losing men in the fourth quarter, suggesting that the situation is growing steadily worse. Virtually all the companies stated they have suffered seriously in efficiency and are now down to the point where any further loss in technical or semi-skilled workers will force a reduction in the number of parties. Already three have been dropped for this very reason and at least ten would have been added except for the personnel situation. It is very unfortunate that such a loss in efficiency has occurred at a time when the difficulty of finding prospects is constantly increasing and it is becoming necessary to drill weaker anomalies which normally would be subjected to very close scrutiny and analysis. The drilling of the great number of wildcats necessary for uncovering needed reserves must not force the lowering of standards to such an extent that the percentage of dry holes will materially increase. To avoid this it is imperative that both the amount and quality of geophysical activity be maintained at as high a level as possible. However, if there is as great a loss this year in the 2-A and 2-B ranks and also of those classified 3-A who are covered by Occupational Bulletins Nos. 10 and 15, then the amount of geophysical activity will, of necessity, be drastically curtailed.

No adequate system of replacements for the 439 men still in classes 2-A and 2-B has been developed although serious efforts have been made. Men over 38 are not interested in this work which requires that they move from one locality to another every few weeks or at most every few months. The rate of pay is not great enough to compensate them for the extremely unpleasant living conditions. Moreover, men above 38 with no technical experience are extremely unlikely to satisfactorily fill the technical positions now being made vacant. Because of the unusual nature of this work the aver-

age age of a field crew is quite low so that little relief was obtained when the Selective Service placed a ban on men over 38. Not over 25% of the geophysical employees are above this age. Women cannot do field work but are being trained as computers as rapidly as possible.

It is necessary to give new men a protracted period of training before they become effective. This is indicated in the table below where estimates of periods of training have been made after consultation with several different companies.

	Period of Training	
	College Trained (Years)	Non-College (Years)
Party Chiefs	2	5
Chief Observers	1	3
Chief Computers	1	3
Surveyors	1	2
Shooters		1
Drillers		1

On the basis of this table it will be seen that the usual allowance of a few months for training which is granted by the Selective Service is entirely inadequate even assuming that men with the proper qualifications could be obtained. A number of the companies have placed their problem before both private employment agencies and the U. S. Employment Agency. They have advertised, they have contacted the various colleges and universities, but with all this have been unable to get recruits. The replacement of our type of labor is not like forming a W.P.A. gang. You can't put a stick of dynamite and an electrical blasting cap in a man's hand instead of a shovel and then tell him to go dig a hole with it.

There has been a decided lack of uniformity in the attitudes of the various draft boards. Some of them seem to doubt that exploration is included in the production of petroleum and is therefore covered by Occupational Bulletin No. 15. This may arise from the fact that many of our important job classifications are not specifically covered in the bulletin. For example, no mention is made of Chief Observers, Surveyors and Shooters, yet without any one of them a party cannot operate. The classification of Driller is included but some boards take this to mean only oil well drillers. Quite a number of important men have been lost even when specifically covered such as Party Chiefs and Computers. Adverse action of draft boards has not been confined to any particular group or to any particular locality. Party Chiefs, Chief Observers, Surveyors, Computers, Drillers, Shooters and even Seismologists, both with and without dependents, have been called by boards scattered throughout the south.

The whole problem is further aggravated by the fact that about 20% of the exploration geophysicists are now serving the government. Of the 20 geophysical companies having substantial laboratories, 15 are more or less fully engaged on various war projects so that virtually no research or development on geophysical problems is now being carried on.

There is no doubt whatever that this problem is extremely serious and deserves immediate attention. Since freezing of men in their positions should be a last resort one or more of the following steps, which will have to be developed through the P.A.W. and the W.M.C., are suggested as a means of alleviating the situation.

1. The issuing of a special Selective Service Bulletin on exploration, or the amend-

ing of Bulletin 15, with the specific inclusion of exploration and the main job classifications therein.

2. A statement from the War Manpower Commission to men engaged in exploration pointing out that they are making their maximum contribution to their country's welfare by remaining in their present positions. (A statement similar to the one recently issued jointly by Secretary Ickes and Mr. McNutt would have a salutary effect if addressed directly to the exploration men.)
3. The establishing of a committee to pass on deferments similar to the recently formed Physicists Committee.

I shall be happy to pursue this subject further with you and to supply any needed information.

Very sincerely yours,
B. B. Weatherby.

Personnel Data in Geophysical Operation

1. No. of Reporting Companies 21	Activity Represented		77%
2. No. of Field Parties January 1, 1942		249	
January 1, 1943		254	
3. a. No. of Employees January 1, 1942		4395	
b. No. of Employees January 1, 1943		4085	
4. a. No. who have gone to the Services		1341	30%
b. No. released to Naval Ordnance, N.D.R.C. and allied work		160	
c. No. to other industries		1768	40%
d. No. hired during year		2959	
5. Was there any decrease in rate of losing men during fourth quarter		4	Increase
		12	No
		5	Yes
6. Shortage was most serious in what classes of men		17	Technical
		4	Semi-skilled workers
7. Has your efficiency suffered seriously		18	Yes
		3	No
8. Are you now down to irreducible minimum (meaning that a further reduction will cause dropping of parties)		19	Yes
		2	No
	(Three companies have already dropped parties because of personnel losses)		
9. Do you have fewer field men per party now than a year ago	Two men less (Av.)		
10. Have you used women in computing		17	Yes
		92	now employed
11. a. How many 2-A and 2-B employees now		439	
b. How many have been drafted		62	or 12%
12. Have men covered by Occupational Bulletins 10 and 15 been drafted		16	Yes
		5	No

96 have been lost out of approximately 1500 in this class, or a 6 to 7% loss.

Deferment requests have customarily been made for supervisors, party chiefs, observers, computers, surveyors, shooters and drillers.

This letter was presented to Mr. Lovejoy and discussed with him on the occasion of the March meeting of the P.I.W.C. It was also presented to several members of the Physicists Committee as well as to Mr. DeGolyer and Mr. Heroy. As you will see later, both of these gentlemen were extremely helpful and gave unstintingly of their time in an effort to start the ball rolling.

Knowing of the recent formation of the Physicists Committee of the War Manpower Commission, whose function it is to go over 42-A deferment requests for physicists for the purpose of making specific recommendations to draft boards in each particular case (incidentally the position of this committee has been very highly persuasive to date), it therefore seemed to be of considerable importance to find out exactly how this committee had been formed since the same route might be available for the possible formation of an exploration committee. Moreover, it seemed absolutely necessary to fully acquaint the members of the Physicists Committee with all our problems prior to their placing the stamp of approval or disapproval on the deferment of any physicist turned geophysicist. It so happened that this visit was very timely for a party chief or two had been up for consideration the previous day and conversations with several members of this committee both in Washington and New York supplemented by a very foreceful letter from Mr. DeGolyer probably resulted in a reversal of the committee's position and a recommendation for deferment.

After finding that the time was ripe for obtaining either a formal extension of the activity of the Physicists Committee to cover geophysicists or possibly even the formation of an Exploration Committee, it was decided that the S.E.G. should direct such a request to the War Manpower Commission. This request has gone forward, I believe, but as far as I know no answer has been received.

A long conference was held with Mr. Heroy, during which it was decided that an attempt should be made to ameliorate the situation through one or more of the following steps: 1. The formation of an Exploration Committee as previously described. 2. To have Mr. Ickes write to General Hershey pointing out the seriousness of the situation and the necessity for maintaining exploration; this letter to be the basis of a general directive from the War Manpower Commission to all draft boards asking them to use the utmost care in refusing deferment requests for our men. Incidentally, it will probably be extremely difficult to carry this step through. 3. To get an amendment to Bulletin No. 15 with exploration specifically included in the preamble so that

there will be no doubt in the minds of any draft boards that it was meant to include this very important phase of production. Several classifications such as observer or operator, shooter and surveyor were also to be added. While men will be lost to the services even with such a bulletin, nevertheless it would certainly be more persuasive on the draft boards than the present Bulletin No. 15. This is now moving forward with a very good chance of success. 4. To get a statement from Secretary Ickes, similar to the recent joint release of Mr. Ickes and Mr. McNutt, specifically directed to geophysical and exploration personnel and pointing out the contribution each and everyone so engaged is making.

The above represents a fairly ambitious program, but it is my understanding that the P.A.W. is moving toward its accomplishment on several fronts.

In reviewing our labor problems it is inevitable that the meetings of the A.A.P.G. and the S.E.G. in Denver a year ago should be recalled when Mr. DeGolyer kept repeating that we should keep every man possible. Although there was considerable opposition to this point of view at that time it is very evident now that his advice was sound.

In order that there may be no lingering doubt as to the potential danger in the production situation a few statements made by men vitally interested in the petroleum industry will be repeated.

In his letter of October 22, 1942, to President Roosevelt, Mr. Cole said:

> Our present oil consumption is now limited by our transportation facilities. Without any increase in transportation facilities and with the present rate of drilling, within a year our consumption of petroleum products will be limited by our ability to produce them instead of by our ability to transport them. . . .
>
> Our needs may reach five million barrels a day in which case there is no present prospect of meeting them and all the tanks and trucks and planes grounded in this country for lack of fuel will be of no account.

In his progress report of October 15, 1942, Senator O'Mahoney made the following statement:

> There was complete unanimity at these hearings among all witnesses (from the War Department, the Navy Department, the Department of Justice, the General Land Office, the War Resources Council, the U. S. Geological Survey, the Office of the Petroleum Coordinator, the Petroleum Industry War Council and the Independent Petroleum Association of America) with regard to the necessity of discovering more petroleum reserves in this country. The undisputed facts revealed are that production of oil has been falling off while the growing war demand may well deplete our known reserves, endanger the conservation policy and in time force us to turn to petroleum substitutes.

In September, 1942, the National Conference of Petroleum Regulatory Authorities, which is composed of representatives from each of the twenty oil producing states and of the Interstate Oil Compact Commission, concluded that:

> America today faces the serious threat of certain shortage of petroleum and its products. . . . The search for petroleum is becoming increasingly difficult with each year. . . . It is the considered judgment of this body that a proper price for crude petroleum is a basic essential incentive to the exploratory work necessary to uncover further petroleum reserves. . . .

Finally on January 26, 1943, Assistant Deputy Petroleum Administrator DeGolyer said:

> We are getting very close to the margin of our productive capacity. . . . Military and essential civilian demands are being met now but war needs will place a real pressure on the nation's productive capacity before 1943 ends.

The following statement appeared in the Report of the Committee on Manpower of the Petroleum Industry War Council:

> It is of course obvious that petroleum is the very life blood of mechanized war. Airplanes, tanks, jeeps, submarines and battleships, are fueled and lubricated with petroleum. Add butadiene for rubber, toluene for explosives, asphalt for runways, and the underlying importance of petroleum in the prosecution of the war needs no further presentation.
>
> But our problem has to do with a gauger in an isolated oil field, with an oiler at a pump station "deep in the heart of Texas," or a geologist pondering intricate data which may lead to the discovery of an important new source of supply. Tell them that what they do, and what thousands of others like them in the many jobs of the industry are doing, is the composite contribution to this essential war industry. To tell them that they are doing their part is an obligation we must recognize and do something about. The gauger running that crude oil is starting a stream that may end in an engine in a tank in Africa, or in a plane over Guadalcanal.

These quotations from widely different sources indicate clearly that a serious obligation has been imposed on all of us; one I am sure we are prepared to meet. It is useless to expect that we can operate unscathed in the maelstrom of the events around us. Let us then direct ourselves to these serious problems with all our energy and ability.

PRIORITIES AND SUPPLIES

E. D. ALCOCK*

In any discussion of priorities it should be kept in mind that the situation is continually changing and that the statements made at this time may no longer hold true by the time this article appears in print.

Practically all geophysical supplies are difficult to obtain and the outlook is very dark for any improvement in the supply situation. Since the geophysical industry has been classified as an essential industry it has had a series of priority ratings allocated to it under priority order P-98b. This priority rating has been raised at intervals throughout the inflation that has taken place in the priority system. In general the geophysical industry has been able to maintain a reasonable degree of operating efficienty. The maintenance of this efficiency has demanded a certain amount of foresight as to the need for supplies and ingenuity in the substitution for critical materials and location of new sources. Another aid in the past was the stock of materials in the hands of local distributors. As these stocks become exhausted an even greater amount of foresight and ingenuity will be required.

The present situation as to maintenance, repair and operating supplies is fairly good. A recent check showed that there were no essential materials or satisfactory substitutes which were impossible to obtain. True, some of the items would require up to nine months to deliver but if sufficient foresight has been exercised this time should not hinder the operation.

The priority system at the present time permits the maintenance of a reasonable amount of inventory and it cannot be too strongly urged that this inventory be maintained at its maximum level in conformance with the priority regulations.

The geophysical industry was recently allocated a blanket priority rating of AA1 for maintenance, repair and operating supplies subject to certain limitations outlined in priority order P-98b revised dated April 1, 1943.

Orders for materials totaling less than $100 may be placed directly with the supplier with the proper certification of the order by the purchaser.

Orders having a total value over $100 but less than $1000 with no single item over $500 may be placed directly with the supplier with

* National Geophysical Company, Dallas, Texas.

the proper certification and a copy of the order must be sent to the regional office of the Petroleum Administration for War.

Orders having a total value over $1000 but no single item over $500 must have the approval of the regional office of the PAW.

Orders having any single item of over $500 must have the approval of the Washington Office of the PAW.

The situation as to capital expenditures is confused at the present time, since a new revision of Order P-98b is expected shortly which will cover this subject. For capital expenditures less than $500 the priority rating AA1 for maintenance, repair and operating supplies is valid.

No attempt will be made in this discussion to describe procedures or to interpret the priority regulations as the subject is too complex. Several commercial services have sprung up since the inauguration of the priority system whose avowed purpose is to interpret the regulations and they have issued voluminous literature on the subject. In cases of difficulty, however, it is always wise to secure an interpretation on the particular case from the local priority board or the regional office of the PAW.

Beginning April 1, 1943, a new priority plan was inaugurated called the Controlled Materials Plan or CMP covering the distribution of copper, aluminum and steel. In the past the priority system distributed the materials in a horizontal fashion. Priority ratings were granted with respect to the essentialness of the item with little or nor regard to the available supply of material. Furthermore, any manufacturer assigned a certain priority rating was equal to any other manufacturer with the same rating. If the supply of material was limited it was a case of first come, first served. Under this system it was possible for a machine gun manufacturer to be way ahead of his production schedule while the airplane manufacturer for whose plane the guns were being built would be behind schedule for lack of some of the steel that went into the guns.

CMP is designed to distribute the materials in a vertical fashion. An example of this method of distribution would be that the allotment of materials to fill a Navy contract for planes goes from the Navy to the prime contractor who in turn passes on the proper allotments to the various sub-contractors making parts for those planes. Sufficient materials are allotted to complete the planes and no more.

Under CMP each secondary consumer or sub-contractor estimates the amount of steel, copper and aluminum he needs to fulfill his re-

quirements for the next calendar quarter. He then forwards these estimates to the primary consumer or prime contractor. The primary consumer then adds his estimates of the requirements and forwards the total to the claimant agency, i.e. Army, Navy, PAW, Office of Civilian Supply, etc. These claimant agencies then forward their total estimates to the Requirements Committee of the WPB.

In this manner the Requirements Committee has an estimate of the total demand for materials for the next calendar quarter. It also has an estimate of the supply of materials which will be available for the next calendar quarter. It is inevitable that the demand will exceed the supply. The job of Requirements Committee is then to trim the demand to fit the supply on the basis of essentialness and to allot each claimant agency its portion of the materials. The claimant agency then trims its demands to fit its allotment and allots to each primary consumer the proper portion of materials and so on from primary consumer to secondary consumer. The receipt of a CMP allotment then is presumed to insure the receipt of the materials from the top to the bottom of the distribution system.

The claimant agency for the geophysical industry is the PAW. The preparation of the estimates of future requirements on the part of the geophysical companies will necessitate considerable work and foresight; however non-cooperation on the part of any company will not only injure that particular company but create a hardship on the industry as a whole.

CMP will go into full effect on July 1, 1943 and it is probable that the future will see other critical materials included beside steel, copper and aluminum.

To sum up briefly: (1) The supply situation is difficult but not impossible. (2) The geophysical industry has been given a high priority rating and proper use should be made of it. (3) Foresight is demanded to allow for the lengthy delays in delivery. (4) Inventories should be maintained at the maximum allowable level. (5) Wherever possible new sources of supply should be uncovered. (6) Ingenuity should be exercised in substituting wherever possible for critical materials. (7) Cooperation should be given to the operation of the priority system and CMP. (8) There is a reasonable hope that by a diligent effort the industry will be able to maintain the operating efficiency at an economic level.

TRANSPORTATION

H. G. PATRICK*

During the past two or three weeks the writer has contacted a number of geophysics operators and contract shot-hole drillers and discussed with them the transportation difficulties encountered in wartime operations. The inquiries were confined to the operators in the southwest and midwest. It is felt that we have a fairly good cross-section of the experiences of the exploration group in these regions. Unfortunately, time did not permit our contacting any of the West Coast operators; consequently, we have no information on the subject from that section of the country. Perhaps representatives of the West Coast operators can supply us with information concerning their transportation problems. We shall attempt in this discussion to give a composite view of the transportation problem based on the experience of those who were contacted. Naturally, it may differ somewhat from the actual experiences of any particular operator.

For the purpose of this discussion the general subject of transportation has been divided into three sub-heads, namely 1) Tires, 2) New Automotive Equipment, and 3) Spare Parts.

Tires

For several months following the beginning of tire rationing most geophysics operators experienced some difficulty in obtaining tire replacements. This, of course, brought about delays in the work. The chief causes of these difficulties were: 1) Geophysics was not specifically mentioned in directives issued to the local tire boards as an industry eligible to receive tires, and 2) in issuing local tire quotas no provision was made to care for the needs of the transient geophysicist. Lacking specific information the local boards were left to their own judgment as to whether we were eligible to receive tires. The more favorable boards, by grouping geophysicists under the general head of Engineers, Production Men or Miners, found justification for issuing tire orders. However, those who took the opposite view refused to grant requests for tires on the grounds that there was no mention of geophysicists in the list of eligibles. This situation was clarified, as was the quota difficulty. Local boards can now get their tire quotas

* Humble Oil and Refining Company, Houston, Texas.

raised to care for the needs of the transient contractors or geophysicists who are doing work in the area of their jurisdiction.

In recent months geophysics operators have had very little difficulty in getting the tires necessary to carry on their work. Most operators feel that there was some improvement with respect to replacement tires after the trucks were registered with the Office of Defense Transportation and Certificates of War Necessity were issued. Whether the improvement was due to the change in setup or to the general improvement in the crude rubber outlook is not known. At any rate, the rubber shortage is admittedly not as critical as it was when the Baruch Committee made its report. In recent public statements Mr. Jeffers has said that there will be sufficient rubber to meet all essential demands. With some synthetic plants now in production and others due to start producing next fall, it is the consensus of geophysics operators that the progress of exploration will not be retarded due to lack of tires. This does not mean that the geophysicists are over-optimistic as to the supply of tires or that they are taking lightly the need for rubber conservation. Neither do they believe that they can buy tires whenever the notion strikes them. They do feel, however, that unless conditions change radically, enough tires will be issued to carry on the work.

New Automotive Equipment

To most geophysics operators the outlook with respect to new trucks and automobiles for replacement purposes is none too bright. In general, it can be said that very few new units have been acquired by the geophysics industry since cars were "frozen." At the time of the "freeze" most operators had good automotive equipment on hand. By retiring non-essential units quite a few of the oil companies created a reserve of trucks and cars, some of which have been available to their geophysics departments. With such a reserve these particular companies became ineligible to purchase new equipment. This "backlog," of course, has not been available to the geophysics contractors except possibly some of the larger ones. Up to the present time not much new rolling stock has been needed. However, in the not too distant future a time will come when much of the rolling stock now in use will have to be replaced, if the work is to be carried on. This time has already been reached, or soon will be, by a great number of the gravity operators. Gravity work, by its nature, requires much driving. Some of the gravity operators who were contacted by the writer have

a number of trucks that have been driven 60,000 to 70,000 miles. Some few have been driven more. These units are fast approaching the end of their usefulness and must be replaced.

It may be well to point out here that so far little difficulty has been experienced in obtaining orders for new cars. It has been necessary in most cases to accept the types and models of cars which are not used by the armed forces. Nevertheless, the geophysicists are glad to get them and willingly pay higher prices for de luxe models and medium priced cars.

In some instances applications for new trucks were denied by the boards with the suggestion that the applicant buy used trucks. For a number of reasons most of the used trucks which are available are not suited for geophysical work. Very few of them will stand up for any appreciable length of time on off-the-highway driving. Their use complicates the maintenance problems and causes further delays in exploration work.

It is realized, of course, that since no new trucks are being manufactured for civilian use the existing supply must be closely conserved. However, it is important that the increasing need for new automotive equipment by the geophysics industry be recognized and that adequate provisions be made to meet the need. The actual number of units which will be required is relatively small, since there are only about 2000 automotive units in use by geophysics operators.

Spare Parts

It seems logical to predict that within the next few months the lack of an adequate supply of spare automotive parts will cause much delay in geophysics exploration work. As a matter of fact, much time has already been lost for this reason. It is our understanding that the automobile manufacturers have been authorized to make 15% more parts this year than they made in 1941. This increase may be sufficient provided the parts are distributed properly and are not hoarded. Steps have been taken to prevent hoarding of parts, among them being the requirement that an old part must be turned in before a new one can be purchased.

The geophysicist's need for a readily available supply of repair parts is much more acute than that of the ordinary truck operator. In the event of a breakdown it is not possible for the geophysicist to transfer his load to another truck and proceed with his work. The mounting of geophysics equipment on trucks is a lengthy and laborious

process. Often when a truck breaks down an entire crew is held up. It is particularly important that the shot-hole drills be kept in operation. In general, the drills set the pace for the seismograph crews. When they fail to run the work suffers.

The problems of automotive maintenance tie in closely with the manpower shortage. The handling of automotive equipment by inexperienced drivers brings about much of the need for repairs. The repairs, in turn, are harder to get due to the shortage of repair parts and the lack of mechanics in local garages.

In summing up the wartime transportation difficulties it can be said that, so far, the oil finding efforts have been carried on in spite of numerous losses of trained personnel and with little new equipment. In the future, however, if a diligent exploration program is to be continued the geophysics industry will need help in the form of new trucks and an adequate supply of spare parts.

THE CONTRIBUTION OF GEOPHYSICAL LABORATORIES

W. T. BORN*

To obtain the information upon which this brief report is based, the following questions were submitted to the executives responsible for the laboratory activities of twenty-four commercial geophysical prospecting organizations:

1. What percentage of your technical laboratory personnel have you lost to
   (a) The Armed Forces?
   (b) Governmental or other laboratories engaged in research and development work on war projects?
2. What are you doing with the men you have left?
3. In your opinion, is the progress of the geophysical prospecting techniques being seriously affected by diversion of technical skill to wartime projects?

Replies were received from 20 of the organizations contacted, employing altogether an estimated 85% of all the laboratory personnel in this field. To all those who contributed information the writer here wishes to extend his sincere appreciation of their assistance.

* Geophysical Research Corporation, Tulsa, Oklahoma.

This information was gathered during the month of March, 1943. All the data submitted were given with the understanding that they would be used only to present a picture of what the industry as a whole is doing, and that no direct quotations from the replies would be made. Those companies presently engaged in research and development work on wartime projects could refer to them only in very general terms since the nature of such projects is secret.

The whole story of the contributions to the war effort which are being made by commercial geophysical laboratories cannot be told until the war is over. However, it is hoped that this brief summary of the work being done will serve to indicate that these contributions are wide in scope and of tremendous importance.

The first contribution is in personnel, engineers and physicists whose training and experience have uniquely fitted them for development work in the techniques of modern warfare. The technical staffs of the geophysical laboratories have long been accustomed to working under pressure in a highly competitive industry. They have had direct personal contact with field conditions often as difficult as those facing our armies in the field. In addition, many of the techniques of geophysical prospecting are directly applicable in modern war. Finally, the fact that the majority of these men have been employed in the petroleum industry is assurance that they are of the type to whom the ability to keep confidential information inviolate has become second nature.

The replies to the first question indicate that some 40% or 50% of the technical staffs of geophysical laboratories have been released to the Armed Forces or to governmental laboratories. The number entering directly into the Armed Forces has not been great. The majority of the laboratories contacted reported that such losses have been negligible. The remainder reported losses ranging from 5 to 30%. The differences between companies may be largely due to differences in their interpretation of the phrase "technical laboratory personnel." Some organizations, also, were largely staffed by men holding Reserve Officer Commissions and these men were called early to active duty. Finally, the differences reflect, to some extent, previous differences in the policies of various companies in requesting occupational deferment for technical men. From the industry as a whole, the writer estimates that some 10% of laboratory engineers and physicists have entered directly into the armed forces.

The contribution of men to governmental laboratories, on the

other hand, has been very great. All companies reported such losses, ranging from a minimum of 3% to a maximum of 60% of the pre-war laboratory personnel. The companies reporting the greatest losses were also those employing the larger staffs. Hence, the average loss for the industry is somewhere between 30% and 40%. In general, these men have been given leave of absence by their employing companies in order to engage in such work. Most of these men are employed by the Naval Ordnance Laboratory and by the several laboratories engaged in developing the art of submarine warfare.

In spite of this loss of some 40% to 50% of trained laboratory personnel, replies to the second question disclosed the amazing fact that 80% of the laboratories reporting are now engaged in direct war work of one sort or another.

The direct war work being done is of two types, namely, manufacturing, and development work. An integral part of practically every geophysical laboratory is a high precision machine and instrument shop, ordinarily employed in building geophysical prospecting instruments. All of the laboratories engaged in direct war projects are employing these shops in connection therewith. From these shops are coming precision ordnance gauges for the Army and the Navy, special tools and dies for the aircraft industry, Radar parts. Other items are a secret device used by the Bureau of Ships, and vibration testing instruments employed by aircraft companies in testing airplanes and in research work on aerodynamic problems. The latter two items mentioned were designed and developed by the laboratories now producing them. The amount of shop time being devoted to war projects is conservatively estimated to be at least 50% of total available man hours. In several instances only 10% of laboratory shop time is now being used for the essential repair and maintenance work necessary to keep the geophysical field crews in operation.

In addition to the precision manufacturing mentioned above, 55% of the laboratories reporting are also engaged in research and development projects, relating to new devices and techniques of offense and defense. Nothing can be said concerning these projects except that they are usually of such nature that the past experience and technical skill of the laboratory personnel can be directly applied. The great majority of these projects are under the supervision of the National Research Defense Committee although a few are being conducted directly for such organizations as the Naval Ordnance Laboratory and the Signal Corps. All of this development work is being done on a

basis which yields little or no profit to the organization conducting it, and in many, if not most, cases, results in an actual financial loss.

For the benefit of those not directly concerned with laboratory activities a few words concerning the National Defense Research Committee (N.D.R.C.), may be of interest. This Committee is organized within the Office of Scientific Research and Development, which was created by Executive Order of the President on June 28, 1941. This latter body is charged with the responsibility of advising the President with regard to the status of scientific and medical research relating to national defense and it serves as a center for the mobilization of the scientific personnel of the nation in developing and applying the results of scientific research to defense purposes.

The National Defense Research Committee consists of a chairman and members appointed by the President, in addition to the President of the National Academy of Sciences, the Commissioner of Patents, and representatives of the Army and of the Navy. It is the duty of this Committee to initiate research and development projects relating to instrumentalities of warfare and to recommend to the Director of the Office of Scientific Research and Development the need for and the character of contracts to be entered into with universities, research institutes and industrial laboratories in order to carry out these projects. The members of this committee and its subcommittees serve without compensation other than expenses connected with their duties. All are physicists of wide experience and broad knowledge. If a recommended project is approved, contracts are given to one or more organizations to carry it out. In practice, the primary contract is usually awarded to a large university which agrees to act as a general manager. It, in turn, divides the projects into convenient subprojects, and enters into subcontracts with a number of laboratories each equipped to carry out one particular phase of the problem. The primary contractor is responsible for the integration of all the activities of the various subcontractors. Great precautions are taken to insure the secrecy of this work. The details of a project, and even its general nature, are not known to anyone not directly concerned therewith.

It is obvious that the diversion of laboratory personnel and facilities from geophysical problems to those of warfare is not a minor movement; on the contrary it is already so great that it offers a problem which must be seriously considered. One of the largest geophysical laboratories reports that it has adjourned its geophysical research and development work for the duration. One of the smaller companies

similarly states that it has entirely abandoned research work on geophysical problems. Another large company states that it is carrying on no research on new methods and that the only development work being done is that necessitated by present conditions, that is, finding substitutes for unobtainable instrument components and substitutes for critical materials. For all practical purposes, research work on geophysical problems, as distinguished from development work, seems to have ceased. Furthermore, even the development of improved instrumentation has become a spare time job for men who have little time to spare. It was a realization of this situation that prompted the writer's request for opinions regarding the effect of the diversion of skill to war problems upon the progress of the geophysical arts.

Those who gave their opinions on the subject were almost unanimously agreed that, up to the present time, this diversion has had little effect on the art, nor has the amount and quality of field work been seriously reduced thereby. Lest this statement be construed, particularly by field men and by management, to mean that the past activities of the laboratories were an unnecessary luxury, it may be well to point out several reasons for this situation. First, during the past few years, the instrumentation of the existing techniques of prospecting had reached a high state of perfection so that existing equipment can be utilized without change until, through research, some radically improved or entirely new techniques are devised. Second, the critical shortage of trained men available for field work, plus the inefficiency inevitably associated with shortages of materials and supplies, are factors which presently overshadow the loss of the usual laboratory support for the field work. Furthermore, under the terrific pressure placed upon the petroleum industry to find new oil fields, the present tendency in exploration work is to range far afield into new areas where the existing techniques are still fairly easily applied, rather than concentrating on difficult areas and attempting to develop techniques to solve the problems they present.

There is general agreement also that the cessation of research work on fundamental problems in the field of geophysical prospecting must inevitably result in a reduction in the prospecting efficiency in the not too distant future. In the event of a long war, with the attendant drain on our rapidly diminishing petroleum reserve, the present lack of personnel to carry on both war projects and geophysical research may prove to be an extremely serious matter. If the war can be terminated within another year or two, the industry can probably catch up with

its problems without much difficulty. Some benefit will be derived from the wartime experience of men who will return to the geophysical field, but it is not likely that this experience will be in the fundamental research which is now being neglected.

In view of the shortage of experienced physicists and engineers in all fields of endeavor, and particularly in the geophysical prospecting industry, it is incumbent upon all laboratories both industrial and governmental to utilize the technical skill available to obtain optimum results. It is the opinion of many men thoroughly familiar with the problem, that it is a mistake to transfer too many men from the commercial laboratories into newly organized governmental laboratories and that the quickest and most economical method of developing new instruments of warfare is to distribute development projects among existing commercial laboratories while retaining their staffs intact. As a result of the information gained in obtaining data for this report, this opinion is shared by the writer. In view of the great contribution in men already made by the geophysical laboratories, it would seem advisable that every effort should be made by the industry to retain the technical staffs still remaining and to effectuate their further contributions to the war effort by increasing, if possible, the development work that can be handled within their own organizations.

SEISMOGRAPH EXPLOSIVES AND THE WAR

W. A. SEYFFERT*

The effective prosecution of the war requires that all essential materials be made available first, to the armed forces, and second, to vital private industries. If this is not done the entire war effort will bog down. We understand that certain persons, evidently laymen, have recently asked whether the seismograph industry might not be handicapping the war effort by its use of one essential material, namely, explosives. These questions were, of course, brought about by the rather widespread idea that the terms "explosives" and "ammunition" are synonymous. Even so, we are surprised that such questions were raised.

It is somewhat logical that this belief should exist in the minds of those not intimately connected with the explosives industry, since for

* E. I. Du Pont de Nemours and Company, Inc., Joplin, Missouri.

about six centuries there was practically no difference between commercial and military explosives. In fact, when you consider the American wars from the Revolution in 1776 until the Spanish-American War in 1898, black powder was the only explosive used and there was very little difference between this powder and our present black blasting powder. Today, however, there is a distinct line of demarcation between military and commercial explosives not only as regards the product, but also in the plants and equipment used for their manufacture.

Present day commercial explosives consist chiefly of black blasting powder and dynamite. The former has been known since the 13th century and for several hundred years was manufactured from potassium nitrate, charcoal and sulphur. Present day sporting powders and "A" blasting powder are still of this composition. "B" blasting powder came on the market in 1857 when an American manufacturer was successful in substituting the cheaper and more abundant sodium nitrate for potassium nitrate. This formula soon displaced the more expensive "A" blasting powder in most commercial work and it is the familiar black blasting powder of today.

Dynamite was invented by Nobel in 1867 and came into wide commercial use in the latter part of the 19th century. For many years even before the present war started the United States has required more than a million pounds of dynamite every day to help produce the vast amounts of ore, coal, oil, and other materials that are so necessary for our national welfare. This is practically all used by private industry since the armed forces use only an occasional small amount of dynamite, mostly for demolition work.

During the Spanish-American War smokeless powder (nitrocellulose, often called guncotton) came into use in a very limited way. In the years between the Spanish-American War and World War Number One, smokeless powder was developed to its present day efficiency and replaced all other explosives as a propellant. Trinitrotoluol (TNT) also came into use about this time as a bursting charge in high explosives shells. These are the two principal explosives used by the nations at war today, and while other materials are occasionally used to replace TNT, their total percentage of the explosives consumed is small.

Many people ask what are the differences between commercial and military explosives and why either one may not serve for both purposes. Let us first consider the commercial type. The explosion of black powder is characterized by large quantities of thick black smoke

and a brilliant flash of considerable duration. These would immediately disclose to the enemy the exact location of our troops and equipment either by day or night. Smokeless powder, as the name indicates, explodes with the evolution of very little smoke and may be manufactured so as to give a dim flash of short duration.

Dynamite has been used in a small way for sapping and demolition operations, but it has several disadvantages which make it unsuited for general military use. It is too violent in action to replace smokeless powder as a propellent explosive since it would burst the gun before the shell had left the muzzle. It is too sensitive to shock to replace the bursting charge of TNT in the shell, as it would be detonated by the shock of the propellent charge and burst the gun. It is too sensitive for practical transportation under combat conditions, as dynamite is easily exploded by the impact of a rifle bullet, while TNT is not. Furthermore, dynamite does not lend itself readily to uniform high density packing in shells. TNT on the other hand melts at 177° F., may be poured into shells or cast into blocks. On cooling, it completely fills the container with a hard, compact charge of uniform density.

And why not adapt military explosives such as TNT and smokeless powder to commercial use? We find that these explosives are much more expensive than dynamite and that they are too weak for many types of rock. They are neither plastic nor granular so that they do not lend themselves well to loading in bore holes. And finally, upon explosion they give off such large quantities of poisonous gases that they cannot be used underground. Dynamite is relatively cheap, can be made with any desired strength, consistency, velocity, or water resistance and may be so designed that there is a minimum of poisonous gases on detonation.

It should also be realized that the plants and equipment used for manufacturing commercial explosives are so entirely different from those needed for military explosives that neither can be converted to manufacture the other. This readily explains why when our country became involved in the present conflict, the government found it necessary to build its own plants for the manufacture of military explosives. Most of these plants are being operated for the government by the commercial explosives companies.

This arrangement separates the manufacture of military and commercial explosives and makes it possible for private industry to secure the commercial explosives needed without interfering in any way with the needs of the armed forces.

Essential private industry such as oil exploration, mines for the production of metals as well as coal and salt could not exist without commercial explosives. The same is true of quarries producing aggregate and flux and large construction projects such as army camps, air bases, and so on. All of these activities are essential for the conduct of the war and must secure materials necessary to keep them going.

The fact that the petroleum industry is given a high priority rating proves beyond question that it is considered one of vital importance. We must know where our oil reserves are. History proves that like everything else, oil wells will eventually pump dry and new fields must be found to replace the old ones. It has been proven conclusively that the most economical way to discover new fields is by seismic exploration. From the above it must be evident that the seismograph industry is an essential one, that it may be proud of the work it is doing, and that it is unquestionably entitled to use the necessary large quantities of explosives in carrying on its work.

PROGRESS OF COOPERATION BETWEEN THE BUREAU OF MINES AND THE GEOPHYSICAL INDUSTRY WITH REGARD TO THE FEDERAL EXPLOSIVES ACT*

G. M. KINTZ†

A year ago in Denver, I had the privilege of discussing with a number of the members of this Society the probable requirements of the Federal Explosives Act as they were understood at that time. As a result of this discussion you appointed a committee with your president, Mr. Goldstone, as chairman, to draw up and submit to D. Harrington, chief of the Health and Safety Service of the Bureau of Mines, suggestions embodying the thoughts of this organization as to how the geophysical industry might be able to change its methods of handling, storing, and transporting explosives, to conform with the Federal Explosives Act without excessive cost. At that time the Army

* Presented by permission of the Director, Bureau of Mines, United States Department of the Interior, before the Annual Meeting, Society of Exploration Geophysicists, Fort Worth, Texas, April 7, 1943.

† Supervising Engineer, District G, Health and Safety Service, Bureau of Mines, Dallas, Texas.

had taken a rather stern but necessary stand and was insisting that guards should be maintained at many of the explosives magazines.

I personally wish to compliment this committee on the splendid manner in which it completed its assignment. Members realized the responsibility of the industry and also the responsibility of and the position taken by the Army and Bureau of Mines officials. The suggestions submitted in general were embodied in the instructions issued in accordance with the Federal Explosives Act. Mr. Harrington commented on these suggestions as follows:

"We are glad to get the suggestions from Mr. Goldstone as they 'clear the air' to a considerable extent on one of the most bothersome phases of a subject which is far more intricate and of more far-reaching importance than any of us thought when we tackled the subject of preparing suitable rules for storage and transportation of explosives."

Because of this committee's work and the splendid cooperation of the field parties and the industry as a whole in endeavoring to comply with the regulations in every practical way, it has been possible for R. D. Leitch, chief of the Explosives Control Division in the Health and Safety Service of the Bureau of Mines to adopt suggestions submitted by this industry. Also, and more important, is the fact that this splendid cooperation on your part, and that of most industries using explosives, has abated the anxiety of the Army officials to such an extent that they insist upon guards at magazines in but few instances and then only after consultation. A high official of the Army stated that, as a whole, he was well-pleased with the manner in which the industry was handling explosives. Thus, much has been accomplished, but the objective has not yet been fully attained.

Naturally, during the past year, it has not been all "clear sailing," as there have been "incidents." Only one of these required a hearing. The results of this hearing clarified a misunderstanding and did not interfere with the company continuing with its work.

During the year, a number of thefts of explosives have occurred; it is important that the details of these thefts be discussed here, so that, if possible, similar thefts can be avoided in the future. Before discussing them, however, it must be understood that making these incidents public is not to be construed as criticizing the companies or individuals involved. Although the law requires that the Bureau of Mines or the Federal Bureau of Investigation be notified as soon as a theft is discovered, the cooperation of the crews in complying with the regulation promptly is appreciated.

Three instances were reported of the theft of explosives from open holes, two of them 80 feet deep and one 100 feet deep. Probably none of these thefts would have occurred had the hole been tamped with dirt or similar material. It is realized that it may cause some inconvenience and perhaps additional cost, but it is *absolutely* necessary that if explosives are to be left in a hole they should either be tamped so that they cannot be removed and leg wires arranged so that they cannot be easily reached or that a guard be placed over them until they are shot. Recently it was reported that one crew made a practice of leaving loaded holes standing until it was convenient to shoot them. This practice is not considered satisfactory or safe.

A detonator magazine was broken into. Evidence indicates that it was done by persons desiring to get the copper lead wires that the shooter had in the past been in the habit of storing in the magazine until he had enough to sell. Storing any material other than detonators or Primacord in such a magazine is forbidden. As the thieves did not find a supply of wire, they took detonators, some of which were recovered. It is believed that boys were the culprits, so it is still possible that they may hurt themselves playing with the unrecovered detonators and may attempt to hold the company responsible.

Two unhooded locks were pried off a seismograph portable magazine and 149 pounds of explosives were stolen. This instance shows why it is recommended that hoods be placed over the locks.

Three months ago it was reported to us by the Army that a geophysical company was storing explosives in an unguarded shack near the coast. It was necessary, of course, to request the company to put a 24-hour guard at the magazine until it could obtain an approved-type explosives storage magazine. The company complied within a few hours—the time necessary to hire the guard and get in touch with the party chief.

It is hoped that it is now correct to say that no party connected with the geophysical industry is storing explosives in an unsafe manner.

During the year, 2 men lost their lives in one accident and 3 others were saved by administering artificial respiration in another accident, both caused by the blasting wires coming in contact with high-voltage power lines. The regulations require that the Bureau of Mines be notified as soon as possible of any accident involving explosives. This requirement is apparently not well known, as many persons do not comply with it. While accidents to members of geophysical crews are few,

they do occur. Every accident, no matter how slight, means lost time. Time is more important during this war than it has ever been before. Moreover, medical care is less available; therefore, it is important that every member of a crew knows how to administer first aid to the injured. Everyone knows that even a slight scratch can mean the loss of days and perhaps a limb or a life. The important item of keeping men on the job may be greatly assisted by first-aid training.

The Health and Safety Service, through its Safety Divison, members of which are under the supervision of the supervising engineer of each district, has first-aid instructors available for training, without cost, anyone in the mineral and allied industries, including, of course, the petroleum and geophysical industries. During the year, instructors from the Dallas office trained a number of crews in the field; there was only one instance, when they approached the party chiefs in which the instructors did not receive whole-hearted support. Ordinarily, at least one if not all members of the parties cooperating completed the course of 15 hours. In the exceptional instance cited, not a single member of the crew attended the class, and no member had had any first-aid training.

Should you desire to receive this training, arrangements will be made to have a Bureau of Mines first-aid instructor contact the parties as soon as possible, if you will send the Dallas office a list of the locations of your various parties. There are only four instructors in this area, so it may take time before they get to your party. A class of 25 to 40 is the most desirable, but not necessary.

The question of keys for locks on explosives magazines has arisen. Our investigators are often delayed because a set of keys is not kept by a licensed person at the office. It is known that, at times, in order to avoid considerable delay to the party in case the one set of keys to the magazine is lost, it is necessary that a second set of keys be kept at some secret place about the field office. The law does not require that a person at the office have the keys to the magazine so that he could let an investigator inspect the magazine, nor are our investigators going to ask, let alone insist, that the shooter or other person stop his work in the field to let him into the magazine, unless it in no way will interfere with the work. An explosives investigator has a tremendous area to cover, and it costs considerable money to keep him in the field; thus, if he has to wait around, we are not getting production from him.

Purely as a favor to the Bureau of Mines, it is hoped that perhaps

you can find it convenient to arrange for some licensed employee at the office to have the keys and to know the location of the magazines. If this man does not issue or handle the explosives it is not necessary that he submit any records. However, he must be licensed to have keys in his possession, or even to know the location of any hidden keys.

It would probably prove advantageous to both the geophysical company and the Bureau of Mines if the company could find it convenient to number or place some other identifying mark on the inside of the magazine so that it might be properly listed and identified by an investigator. In this way, it would be easier to determine whether or not the magazine had been previously inspected and approved, and thus perhaps avoid conflicting recommendations. While we endeavor to have all investigators require the same standards, the personal element enters in our work the same as it does in yours.

There are available, here, copies of the latest amendments to the regulations. There are practically no changes that materially affect your industry, except that persons in charge of transporting vehicles must be licensed individually. However, these late amendments should be read carefully.

Renewing of licenses has presented some problems that have had to be solved.

Your attention is directed especially to Paragraph 301.10 regarding copies of licenses, as a number of copies have been submitted that are not properly numbered or signed. If these copies are not properly made out, they are not valid.

The interest all of you have taken in the safe handling, use, and storage of explosives is most gratifying to the Bureau of Mines officials. The issuance of a blaster's manual and instructions on storage and handling of explosives similar to those recently published by the National Geophysical Company, is a practice recommended for your consideration.

It is sincerely hoped that the actions of the investigators and the Bureau of Mines personnel have proved that it is not the purpose of these men to endeavor to catch anyone in an act for which he can be prosecuted, but rather to help you to comply effectively with the Federal Explosives Act in a manner involving the least expense and delay. Also, we hope that you will not hesitate at any time to call on the Bureau of Mines for assistance.

During the year it has not been a chore to work with you; it has been a pleasure and an education to every member of the Explosives Control Division. Therefore, the most important part of coming before you today is to express, on behalf of the Director of the Bureau of Mines, R. R. Sayers; Chief of the Health and Safety Service, D. Harrington; Chief of the Explosives Control Division, R. D. Leitch; and each of the personnel of this district, their sincere appreciation to each of the officials and the field men connected with and using explosives in the geophysical industry, for their whole-hearted cooperation, which made it possible to accomplish so much in such a short time.

THE GEOPHYSICIST AS A FORECASTER*

PAUL WEAVER†

ABSTRACT

The commercial geophysicist has hitherto been little concerned with a realm of geophysics which deals with the detection of non-equilibrium by measuring the time-rate of change of a physical property in a localized area, in order to forecast when a critical point will appear in the system, and what magnitude of transition is probable. The author has selected some examples of such geophysical problems, which he considers of great economic importance, and which would appear amenable to our present technique or to some modification thereof. There are discussed:

1. Artificial non-equilibrium.
   (a) Wells, mines and quarries
   (b) Extraction of underground fluids
2. Natural non-equilibrium.
   (a) Weather, particularly fog
   (b) Earthquakes and landslides
   (c) Volcanoes.

INTRODUCTION

Many exploration geophysicists are alarmed at the diminishing returns from structural mapping for petroleum and are looking ahead to the post-war era, when many trained geophysicists will return from military service and will wish to re-enter commercial work. The author believes it will be profitable to investigate other lines of geophysical research and utilization, and he suggests that there is a whole realm of geophysics in which it is patent that great economic advantages would result if the problems could be solved. This realm is distinct from that in which the commercial geophysicist is now engaged where he studies an invariant physical property (static), in that the subject proposed for study is a changing physical property (dynamic), and therefore continuing geophysical measurements over a greater or less period will be required on each job.

THE STATICS OF GEOPHYSICS

In the first sentence of the introduction to his treatise, *Geophysical Exploration*, Heiland defines geophysical exploration as "prospecting for mineral deposits and geologic structure by surface measurements of physical properties."[1] *Prospecting* literally means looking ahead,

* Presented at a luncheon meeting of the S.E.G. held at Hotel Texas, Fort Worth, April 7, 1943.

† Gulf Oil Corporation, Houston, Texas.

[1] C. A. Heiland, *Geophysical Exploration*, Prentice-Hall, Inc., 1940, p. 3.

and is a form of forecasting, because the purpose is to predict what will be found underground below a certain point on the surface.

The Society of Exploration Geophysicists devotes most of its publishing activity to the province of exploration geophysics as defined by Heiland. This province is primarily concerned with structural conditions which are assumed invariant in the span of time during which we survey, explore, and exploit a mineral deposit on the structure. Therefore it is logical that an acid test which we apply to the success of field technique of this form of exploration is that the observed quantities measured shall be reproducible. This realm is called the Statics of Geophysics.

THE DYNAMICS OF GEOPHYSICS

There is another realm contrasted with the preceding one, where the object of the investigation is the time-rate of change in structural conditions, and the author defines it, in terms parallel to those employed by Heiland, as *prospecting for mineralizing processes and geologic incompetence by surface measurements of the time-rate of change of physical quantities*. The purpose of this kind of exploration is to locate non-equilibrium conditions, and to forecast *whether* a release of strain will occur, *where* it will be most intense, and *when* it will obtain dimensions sufficient to jeopardize human activities or life itself. It will be obvious from the definition that this realm of geophysics can appropriately be called the *Dynamics of Geophysics*, and that a geophysicist devoting his efforts to solving the several problems is *prima facie* a Forecaster.

There is an important distinction between personnel activity in the two realms of Statics and Dynamics. An exploration geophysical survey is a job which, once done, is finished. A subsequent survey, using the same technique, should add theoretically nothing to the data nor the deductions therefrom. A non-equilibrium survey must be repeated whenever there is passage through a transition point, and only when and where the change of state be complete, would there be no further survey desirable.

In the following paragraphs, a few cases of non-equilibrium conditions are discussed, and in the order from those simpler in basic conditions to those more difficult. It will be apparent that a case of non-equilibrium caused by the movement of a finite and measurable mass of material at a finite and measurable rate is the most simple form of non-equilibrium because: (1) the locus of the disturbance is known in

space; (2) the zone of effect of the disturbance is generally accessible for measurements. These conditions obtain in the cases which we shall call artificial non-equilibrium, two of which are as follows:

A. Drilled wells, mines and quarries.

B. Extraction of underground fluids.

NON-EQUILIBRIUM CAUSED BY DRILLED WELLS, MINES, AND QUARRIES[2]

Artificial Non-equilibrium: Wells

When a well is drilled, it is quite frequently observed that the size of the hole does not "hold to gauge." Some wells show "crowding," that is, the diameter decreases; others showing "caving," that is, the diameter increases. The caliper log has provided us with a means of measuring the change in area of cross section of a drilled well and has opened up the possibility of studying the response in adjacent wells of various kinds of rocks, with different configuration and position on structure.

We may hope that a study of caliper logs by geophysicists will eventually permit a more scientific program of casing for wells, and will reduce time and financial loss in drilling of the wells by eliminating stuck drill stem, etc.

Artificial Non-equilibrium: Mines

Mines show a gradual movement of the walls, roof, and floor of tunnels and other workings. Where this creep is continuous and slow, it adds, to the overall cost of mining, the cost of timbers and other supports, and limits the size of the ore bodies which can be removed without the movement extending into adjacent zones of rock.

However, there are two aspects of this movement of serious import to safety. The first is that the movements in the mine-workings are not all of the slow continuous type, but are frequently sudden, and in the extreme case, of an explosive type—rock masses of some size blowing out from the face. These latter are known as "rock bursts,"

[2] In considering these three groups, we shall simplify the problems presented by disregarding the chemical non-equilibrium. As is obvious, the removal of cuttings from a drilling well, and of ore from a mine or quarry, exposes a surface of rock to fluids different from those with which it was previously in equilibrium. No discussion of chemical non-equilibrium in any of the succeeding paragraphs will be attempted, as the subject is one which deserves a special presentation. For the same reasons, biological effects which are obviously always of a non-equilibrium form, will also be omitted.

and account for a great proportion of the casualties in mining.[3] Despite the seriousness of this problem, from the human factor alone, a relatively small amount of geophysical work appears to have been done, and few of the results have so far found their way into print. The attitude of most mining engineers is that the rock bursts just happen, and are not subject to forecast. To quote one of the most experienced ones:

"Bursts of this type are unpredictable and unpreventable, though sometimes the course of a zone of weak rock, of a fissure or fault can be anticipated, and in ends approaching grounds of this nature extra precaution can be taken."[4]

The geophysicist Weiss, who has studied the problem in a single mining district, is more hopeful that some remedies are possible. He states, after describing his observations, but without mentioning any geophysical measurements as having been made by him:

"The question arises as to whether the recent developments in physics and geophysics can contribute to a better understanding of the nature of the rock bursts and to the increased safety of mining. It is the writer's opinion that the avenue of investigation is full of encouraging promises, and that the better understanding of the physics of rock bursts will be the most important field in the mining research of the coming years."[5]

The author is of the opinion that until geophysical experiments have been conducted *ad hoc*, we cannot be sure we shall be able to forecast rock bursts. We do know, however, that practical miners for generations have used the crudest form of elastic tests for determining the variation of velocity of sound in the walls and roof of a mine opening, in order to estimate the instability of the rock, and it is therefore suggested that technique of the seismograph should be tested in this very important field of non-equilibrium.

The second aspect of movement of rock in connection with mining which is of serious importance to human life and human activity is the subsidence at the surface over areas being mined, or which were mined in the past.[6] Legislation in many jurisdictions and the common law in others has stipulated the obligation of the miner to minimize or prevent surface subsidence, but how it occurs, and the conditions under which it may be forecast, are not yet the province of scientific

[3] For a general discussion of recent opinions on rock bursts, see P. B. Bucky, et al., "Rock Bursts," *A.I.M.E. Technical Publication* 1468, 1942, reprinted in *A.I.M.E. Mining Technology*, May 1942.

[4] *Op. cit.*, p. 6.

[5] *Op. cit.*, p. 21.

[6] For a general review of mining subsidence see C. B. Wagner, *A Report on Subsidence Literature Survey and the Law on Subjacent Support*, West Virginia University, Bull., July 1941.

formulation, much less the prediction of when, and how much, surface subsidence will correspond to a known extraction of ore as of a certain date, at a known depth.[7]

Yet, the problem does not seem too vague. Measurements are possible above ground and usually also in the mining area; the subsidence in most cases is a progressive stoping, affecting first the strata immediately overlying the mining area, and successively those above toward the surface, which must thereby successively show change in the number of discontinuities and in other bulk properties. To mention only one, rearrangement of porous strata changes water-table levels and water yields from drilled wells and from surface springs.

Many mine workings extend under railways, roads, cities, towns, and villages, and a forecast as to the probable future date of surface subsidence would be so valuable it would seem justifiable to investigate the subject.

A single example will point the moral. A consolidated school costing hundreds of thousands of dollars was built in a village. Today all the houses (frame structures) have been moved away because of minor subsidence, and the trustees dare not use the school, for fear of a sudden major break in the surface.

Artificial Non-equilibrium: Quarries

In addition to the vibrations caused by the use of explosives in excavation and other open cuts, the surface in the vicinity of such excavations may be affected by flowage towards the excavation or by change in physical properties of the shallow strata due to lowering of the water table. One of the most important cases of this kind is the excavation of the open-cut type of subway in cities where there are large buildings adjacent to the location, and where the formations being excavated require unwatering incident to economical construction of the subway. The effect of such unwatering is to increase the apparent thickness of the weathered layer, similar to that observed when water

[7] Henry Briggs, an authority on the subject of mining subsidence, has expressed the following opinion: "Subsidence will always present an appearance of inscrutable capriciousness. Mining subsidence is not amenable to mathematical analysis and still less to mathematical synthesis. Empirical formulae are sometimes useful as guides and will probably become more so as experience extends and is made more fully available." (H. Briggs, *Mining Subsidence*, E. Arnold & Co., London, 1929.) The author would emphasize that Briggs does not mention geophysical surveying and the measurement of physical properties of the overburden as a probable line of investigation for a basis of analysis.

level drops in a large river with high banks, and the water table is consequently lowered in the adjacent river valley deposits.

Electrical resistivity measurements and seismic weathering profiles are both adequate to survey such a situation, but in a city both may be inapplicable, due to interference by city noise-level.

Artificial Non-equilibrium: Extraction of Underground Fluids

Below the surface of the ground in porous strata ("reservoirs" in the language of the petroleum engineer) the fluids are usually under a hydrostatic head which, in many cases, is sufficient to cause the fluid to flow through a well to a level above the surface of the ground. When the fluid is being extracted at a rate greater than the permeability near the well permits the hydrostatic head to move additional fluid into the zone of exploitation, there is created a condition where a portion of the reservoir has its pores voided of fluid, and under such condition it is possible that there will be a rearrangement of the grains of this portion of the reservoir, a change in volume of the stratum, involving subsequently movement of overlying strata, and finally of the surface.

Subsidence in the Goose Creek field was attributed to the removal of oil and gas from some of the reservoirs.[8] Two more completely documented cases of subsidence of the surface in areas where there have been heavy withdrawals of underground fluid are the Santa Clara[9] and San Joaquin Valleys of California. The San Joaquin Valley case if of special interest to geophysicists, because in the area of surface subsidence, there has been extensive seismograph work, and this activity was actually considered a factor contributing to the subsidence! The location of this subsidence is in the vicinity of Delano in T. 24 and T. 25 S., R. 25 E., Tulare and Kern Counties. The map (Fig. 1) and cross sections (Fig. 2) showing the subsidence are taken from a published abridgement of a paper by Ingerson, and his pertinent statements regarding the subsidence are as follows:[10]

[8] L. C. Snider: *A Suggested Explanation for the Surface Subsidence in the Goose Creek Oil and Gas Field, Texas.* Bulletin A.A.P.G., vol. XI, part II, pp. 729–745 (July 1927).

[9] Tolman, C. F., and Poland, J. F., *Ground water, salt water infiltrations, and ground surface recession in Santa Clara County, California.* Am. Geophys. Union, Trans. 1940, pt. I, pp. 23–34.

[10] Irvin M. Ingerson: *The Hydrology of the Southern San Joaquin Valley, California, and its relation to imported water supplies.* Am. Geophys. Union, Trans. 1941, pt. I, pp. 20–49.

"The cause of this subsidence cannot be definitely stated at this time, and only apparently coincidental phenomena can be pointed out. These phenomena may be effective to a greater or lesser degree, as follows:

"(1) The greatest total lowering of the ground-water from 1921 to 1939 in the Upper San Joaquin Valley occurs within this subsidence-area but not entirely concentric

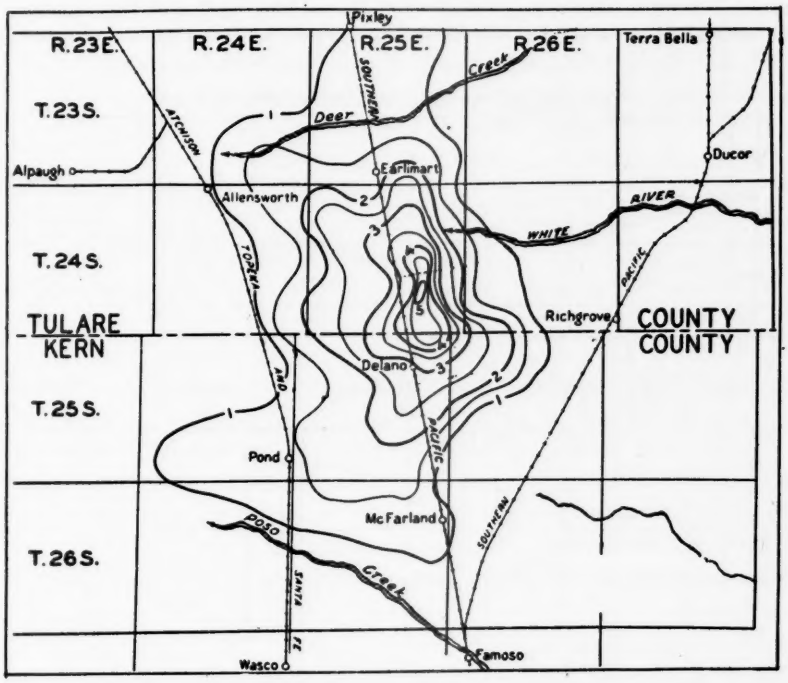


FIG. 1. Lines of equal subsidence 1902–1940 in Delano Area, California. Contour interval of 1 foot.

thereto. Reference is made to Fig. 1, showing lines of equal total lowering. The average total lowering in this period has amounted to approximately 100 feet. This indicates a strata of unsaturated valley-fill material which probably has never before been drained and which was originally deposited under water.

"(2) The texture of soils underlying the affected area is extremely fine, consisting of horizons of clay and sandy clay with considerable colloidal material therein. The area is located midway and farthest removed from the mouths of the perennial streams of the Tule River and the Kern River.

"(3) During the past decade extensive geophysical exploration by means of deeply set explosive blasts has been made throughout the breadth and length of the Valley including this area in question. Serious damage to the irrigation-wells of certain land owners has resulted directly from these explorations.

"(4) The Southern Pacific Railroad operates many heavily loaded trains every day throughout the length of the affected area and the vibration due to the train is felt through the ground for great distances away from the track.

"In the light of these phenomena tentative explanations of the subsidence might be presented. The outstanding factor appears to be that the excessive lowering of the water-table in the fine-textured lacustrine soils has left an unbalanced static support under the 100-foot thick overburden of surface-soils. When the deeper soils were saturated, the forces of surface-tension, cohesion, and buoyancy together with a certain amount of

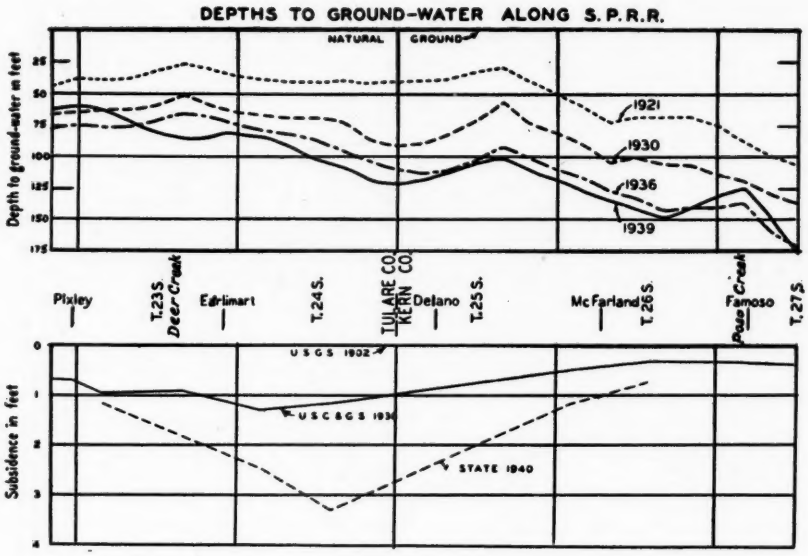


FIG. 2. Depth to ground water and subsidence profiles 1902–1940, in Delano Area, California.

vertical uplift force against the upper impervious strata by artesian pressure all tended to support the surface of the land. But when as much as 60 feet to 100 feet of subsoil was left unsaturated, all of these forces were lessened or destroyed and any amount of ground-vibration would immediately cause settlement and compaction of the materials to a point where the supporting forces were again equal to the load. A natural compaction or settlement of from three per cent to five per cent in clay-soils from saturated to drained conditions has been repeatedly observed and allowed for in excavated and earth filled structures.[11]

It has been a frequent experience in seismograph exploration that the velocity and thickness of the weathered layer vary with depth to

[11] *Op. cit.*, p. 42.

ground water in certain areas, and that a lowered ground-water level decreases the effectiveness of reflection seismograph exploration by decreasing the response from deeper horizons. A series of special measurements with the seismograph, therefore, would seem useful to determine the excessive lowering of ground water and the creation of a zone within the ground-water reservoir in which water has been practically voided. It could therefore probably be predicted that underground movements in the reservoir with possible extension up to the surface, could be expected. Such a prediction and the publication of its significance to interested local parties might be desirable from the standpoint of the purely selfish interests of the party doing the seismological work by enabling him to forestall certain claims for damage to the exploitation of underground water. It will be noted from the quotation from Mr. Ingerson that: "Serious damage to the irrigation wells of certain land-owners has resulted directly" by geophysical exploration, "by means of deeply-set explosive blasts." Is it not very likely that damage to these irrigation wells is primarily due to the settling of the ground and that the seismograph work could have, at the most, only the effect of drawing attention to a change in the regimen of the wells which had been progressing for some time? It will be observed that the use of the word "blast" by Mr. Ingerson is certainly an exaggeration considering the size of the charge used in seismograph work, and the extremely limited area within which each one of the shots causes movement of the ground of any megascopic amplitude.

The extraction of underground water, to mention the most generally utilized fluid, has been accelerated in areas where the demand has been increased by an increase in population. We may mention among the largest cities where water is extracted within the city limits, and in the vicinity of valuable buildings: Hamburg, Bremen, Honolulu, and Houston, and in each of these cities there has been a lowering of the water table as a result of concentrated withdrawals, thereby creating a condition similar in kind, although possibly under different geological conditions, to those obtaining near Delano where the subsidence has been conspicuous.

It will be found in certain areas where water is being removed from deep mines that a part of the water in the mines may be coming from around the shaft, and therefore that the water table in very shallow aquifers near the surface is being lowered and a threat to surface buildings is being created, possibly as serious as the danger of sub-

sidence due to the extraction of the rock from the mine itself. Of course, the investigation of lowering of ground water under these conditions presents a problem which could probably be handled without any aid from geophysics. In general, shallow water would be of different composition from that coming from the strata in which mining was carried on; furthermore, the lowering of ground water near a mine shaft would generally be very localized, and since mines are usually in hilly areas such lowering of the water table will result in drying up or reduction in flow of surface springs and surface streams, as has actually occurred in West Virginia and Pennsylvania. Geophysical investigation still might be useful, however, to determine whether the lowering of ground water had created a serious situation of instability and therefore whether any damage to surface equipment or edifices might be imminent. Of course, the mine owner would be just as much interested in subsidence caused by removal of ore from the mine as he would be in that caused by lowering of ground water near the surface in the vicinity of the mine. The difference between the two causes is that it is probably much easier for him to remedy a situation caused by water going down outside the shaft into the mine, and much more to his personal interest to do so because he will thereby decrease his pumping costs.

The subject of subsidence due to the extraction of fluids is one which the author feels will be more and more important in the future, because there are many areas, especially those of great demand for ground water, where the strongest pressure will be applied to the hydrologist to recommend greater rates of extraction, and it will be difficult to convince the respective authorities that the lowering of ground water is a serious matter because it may be assumed that extraction of large quantities of water is of no permanent damage to the reservoir, on the theory that the pumping can later be reduced and the reservoir will recharge.

It it can be established by numerical values, obtained by geophysical investigations, that the configuration of the reservoir is modified by lowering of the water table, and that surface subsidence is likely to be one of the results of this modification, there will be greater caution exercised before this condition of non-equilibrium be allowed to be set up. It is therefore the thought of the author that periodic geophysical investigation is justified in any case of large withdrawals of fluids from beneath areas where there are important surface edifices.

This subsidence caused by extraction of fluids from a porous reservoir is the result of non-equilibrium of a different type than the subsidence caused by the removal of a part of the reservoir rock itself simultaneously with extraction of fluid, as in the case of a "gusher," a flowing oil well producing by natural flow both fluids and solids—oil, gas, and sand; or in the case of sulphur and salt wells where the ore is extracted in liquid form, although present below the ground as a solid.

All of the non-equilibria just discussed—from wells, mines, quarries, etc.,—are similar in that the volume of solids and fluids extracted is known, and in most cases also are known the location of the zones from which the extraction was made, and the time-rate of extraction. Furthermore, the pertinent physical properties of the rock adjacent to the zone of extraction can usually be measured. The author proposes that there are enough measurable factors to justify geophysical attack on these problems, especially if the survey be initiated when extraction begins, and be continued during extraction. If a proper program of such a survey be carried out, it should be possible to make some reasonable forecast as to when and where undesirable effects may transpire.

NATURAL NON-EQUILIBRIUM

In this class, the masses involved are usually large, the forces may have been operative through an unknown period, and the loci of strain may be difficult to locate by readily observable data. Therefore, the problems are more difficult to formulate as to geophysical attack than in the cases of artificial non-equilibria which have just been discussed. There is, however, ample justification for planning a campaign in one or more of the provinces where natural non-equilibria are present because the service to society, or to large groups of people, will be greater than in investigations of artificial non-equilibria.

Release of strain involving large masses of either solids or of fluids frequently brings about catastrophic movements. Although study of such a condition of strain will not enable steps to be taken to prevent the subsequent release of the strain, nor to decrease the zone affected thereby, a forecast as to the time of release would enable protective measures as to the safeguarding of life, at least. Some of the hazards were not serious in the past epochs of history, but are now more significant due either to greater extension of populous areas or to the acceleration of schedules of transportation.

METEOROLOGY

Weather forecasts in the past have been based on the study of the masses of air and water of continental dimensions. They have therefore predicted average conditions affecting large areas. Many human activities now are localized, and a single meteorological problem, that of fog, will be discussed where this localization is important to a particular phase of human activity, and where geophysical data recently available seem to suggest an appropriate method of attack.

Fog is a serious handicap to transport by airplane. It is also in many cases a very localized phenomenon and tends to be accentuated in the vicinity of large cities where airfields are most numerous, and where hazards resulting from forced landings are most serious. What weather conditions produce fog and how long a time before the incidence of dense fog at a certain airfield are these conditions operative, and how far away from the field must observations on these conditions be made?

For a number of years the ionization of the atmosphere has been studied, particularly by the Department of Terrestrial Magnetism of the Carnegie Institution. Comparison has been made of the relative ionization over land and sea[12] and of the correspondence between ionization and barometric pressure,[13] and studies of the proportion of different ions present. It happened that "an abnormally large-ion count was noted at Washington during the night of December 3–4, 1941. The sudden rise in count preceded a widespread fog along the North Atlantic Coast, reported as being the worst in the past five years. Comparison of the ion-count record with the record of visibility observed at Bolling Field, showed that the concentration of large ions had risen to an unusually large value about seven hours before the fog set in, decreased during the fog, and increased to a large value again after the disappearance of the fog. Another dense fog formed during the next day, but unfortunately, no ion-measurements were made at this time."[14]

The article of which the preceding sentence is a quotation, presents a comparison of large-ion concentration, humidity, and fog for 554 days, and states: "A high nuclei-content as a precedent to fog-forma-

[12] L. H. Gray and G. T. P. Tarrent, Proc. R. Soc., A. *143*, 681–706, 1934.

[13] W. Kolhorster and L. Tuwim, in *Ergebnisse der Kosmischen Physik*, Akademische Verlagsgesellschaft, Leipzic, 1931, pp. 104–124.

[14] M. L. Phillips: *Association of Large Ions and Fog.* Terr. Mag. and Atmos. Eiec., vol. 47, No. 4, Dec. 1942, p. 295.

tion may be required," in other words, there is a physical property (the number of large ions in the atmosphere) which changes *before* (by some hours) the manifestation of a transition phenomenon (the condensation of water vapor to form a fog). Here we have a method for a prediction of local fog based on measurements with a geophysical instrument already available, but hitherto applied only to general research in cosmic physics. It is true the observations on humidity and other of the usual weather data were not made at the same spot as the ion counts, but the distance was fairly close (4 miles), so the correlation is justifiable.

This study by Phillips, made in 1941, on information collected by two different organizations without any idea of a program of definite coordination, is obviously not an example of the best way to make progress in forecasting; rather should measurements be made so that they are simultaneous, of uniform quality, and in accordance with some analysis as to the accuracy desired in order to establish a particular correlation. Work of this latter type is being carried on in the new Cosmic Terrestrial Laboratory at the Massachusetts Institute of Technology, and although this laboratory has been operating only a very short time, it is already reporting some promising results in the field of local forecasting, as indicated by the following quotation:

"The onset of a sudden shower is almost invariably preceded by a discharge of 0.50 micro-ampere in the direction of sky to Earth. This may last for an interval of minutes or several hours. . . . A snow-storm is almost invariably accompanied by periods of oscillating discharges of an hour or more each, first in the direction of sky to Earth, and second, Earth to sky."[15]

The experience which the commercial geophysicist has with electronic instruments of a variety of types particularly fits him to make suggestions as to types of measuring devices to be used in local forecasting. For an example, there seems to be no information which has been collected on a statistical scale, as to how much radioactive elements are present in the dust at different seasons. Can ionization of the air by them be a factor in local weather? Any program that would enable a forecast of flash rainstorms which are so devastating in some parts of our Southwest, would justify a somewhat extended series of investigations. Such local forecasting is entirely outside the present scope of official weather forecasting, which concerns itself only with broad regional probabilities.

[15] Am. Geophysical Union, Trans., Pt. II, 1942, p. 300.

EARTHQUAKES

Movements of the surface of the Earth of catastrophic magnitude, include not only earthquakes but land-slides and snow-slides. All three of these phenomena have been considered susceptible as to their actual time of occurrence to the so-called trigger action, that is, some source of fairly rapidly varying but small stress which determines the release of strain already at a transition point. The author submits that such a picture should be thoroughly examined from the quantitative aspect by geophysics, and that such a study is likely to demonstrate the fallacy of this very popular viewpoint.

As regards earthquakes, discussion has been extensive in the literature regarding the application of measurements of slow changes in geodetic position and in level between adjacent points as indicating a region of instability and one where future earthquakes are likely to occur. The latest viewpoint as expressed by Hodgson,[16] is that a great number of earthquakes, perhaps the majority of them, have foci at depths of the order of tens of miles, and it is therefore somewhat questionable as to whether there be any prior surface manifestations of the building-up of the strains which are eventually released by these earthquakes.

With regard to the problem of land-slides, a great number of these are caused by the lubrication of joints and bedding planes by excessive moisture content. It is believed that this condition can be ascertained by a proper geophysical survey based on a study of the local geology, and such movements are usually long-continued from the time of inception to the time of gravity shifting of a substantial part of the mass involved, and therefore deserve continuous investigation.[17]

Snow-slides and avalanches are caused by the accumulation of large masses on steep slopes, where the climatic conditions have permitted freezing and thawing so that the profile of the snow is made up of layers of different physical properties, and usually contains, near its base, free water. Therefore, sampling of characteristic profiles together with geophysical investigations to give the average condition, should enable a forecast to be made as to the development of slight

[16] E. A. Hodgson: *Interior of the Earth viewed in its relation to earthquake causes,*" Bull. Geol. Soc. Am., vol. 53, No. 7, July, 1942, pp. 1045–1054. The prediction of earthquakes by continuously recording seismographs set up on known faults was discussed in: E. A. Hodgson: *A Proposed Research into the Possibilities of Earthquake Prediction,* Bull. Seis. Soc. Amer. vol. XIII, No. 3, Sept., 1923.

[17] William J. Miller: *The landslide at Point Firmin, California,* Scientific Monthly, *32,* No. 5, pp. 464–469 (May 1932).

movements which probably precede the sudden movement of large masses. In connection with snow surveys by power companies and by forest surveys in the Western States, much information has been collected which would serve as an adequate basis for the formulation of a program to attack this problem.

VOLCANOS

The mechanism which results in volcanic outbursts would appear to be equally as difficult of prediction as earthquakes, because the high temperature of the rock poured out suggests a relatively deep source within the Earth of the mass. This somewhat hopeless viewpoint was expressed by Karl Sapper as follows:

"Since geological field studies can neither give an adequate explanation of the connecting passages between surface and deep-seated structure of volcanos, nor determine the depth or the form of the magma hearth which feeds volcanic eruptions, we must for the time being give up the hope of satisfactory information until new and hitherto undiscovered methods of research have been found."[18]

However, in more recent years, a theory is being investigated which gives more promise for a place for prediction of eruptions. This theory has been expressed by Perret as follows:

"I have postulated the existence of this condition in the mounting magma of vertical volcanic conduits: concentration of the lighter vapor above the liquid through gravitational differentiation. The resulting gas head to the magmatic column forms a boring agent *par excellence* through its power of penetration, disintegration, and fusion, and gives to the column of magma an upward progression, that is, outward to the earth's surface and thence up through whatever edifice may have been formed."[19]

The picture of an area of volcanic activity depicted by Perret will be recognized by the commercial geophysicist as exactly analogous to many oil fields, that is, there is a body of one fluid overlain by another—in the case of the volcano, the lower fluid is the magma and the upper is the gas; in the case of an oil field, the lower is the oil and the upper is the gas cap. The difference between the two is that in the case of the volcano the gas cap is an active chemical solvent, and is eating upward into its cap rock, whereas, in the case of an oil field, the gas cap is at best merely leaking at a slow rate towards the surface, and cannot move upward towards the surface as a mass because it cannot dissolve the over-burden. In the hypothesis of Perret, an

[18] *Physics of the Earth*, Pt. I, p. 17, National Research Council Bull. 77, 1931.

[19] Frank A. Perret, *The Volcano-Seismic Crisis at Montserrat 1933–37*, The Carnegie Institution of Washington Publication No. 512, June, 1939, p. 49.

eruption takes place when the solution by the gas above the magma of the overlying rocks has enabled it to come close enough to the surface so that the cap is no longer competent to restrain it.

This picture means that there must be a very large volume of this gas, as has also been demonstrated by the fact that most volcanic eruptions are accompanied by large quantities of gas compared to the amount of solid matter. The geophysicist could certainly determine the physical properties of the over-burden above a magma, and I do not think it is too much of a problem to attempt to measure the progressive increase in the gas cap over the magma by seismic methods, and possibly also by electrical measurements. Since there are a number of volcanos on the Earth which have shown, either as individual events or as localized groups, a periodicity, these would be the ones to test out our geophysical possibilities, because we could take a period of time which would correspond to the gradual accumulation of gas above the magma and see what changes are observed with time in the geophysical picture. It would seem also that the geophysicist can suggest equipment suitable for measurements during eruptions, since a great deal of this information must be obtained at some distance from the actual crater, or after the material has become cooler. Possibilities of aiding in the determination of the temperature of the magma and of the gases, is interestingly shown by a recent study which has been made of the effect, on steel[20] of the material thrown out from which it has been concluded that the temperature at the time of reaction with the steel was between 1090 and 1260°C. The determination of what ranges of temperature may be expected in different volcanos will help in the planning of a geophysical program, because it will give some idea of the temperature and depth of the magma.

CONCLUSION

The author has very briefly taken up some problems of great interest to society which, he believes, justify the attention of the geophysicist. As to the solution of some of these problems, the author believes that we have a sufficient experience from our work to contribute immediate valuable suggestions, provided that we are allowed to make observations over a sufficiently long period to determine the trend of the state of non-equilibrium which has given rise to the prob-

[20] *Nails from ruins of St. Pierre*, Metal Progress, vol. 41, No. 2, February 1942 pp. 208–11. Article by G. H. Enzian, H. F. Beeghly, and P. P. Tarasov.

lem. As regards others of these problems, and these are some of the greatest interest, a long period of experimentation—probably by the use of very much modified technique—affords the only reasonable chance for their solution. The type of problems presented of non-equilibrium states are new to the commercial geophysicist, but the opportunities which they present of rendering great public service would seem to justify an investigation, not only of the ones mentioned by the author, but of those still to be formulated; and if the geophysicist can present timely and accurate forecasts of the progress of these phenomena he will be assured of an ever-widening field of professional work.

SECONDARY ARRIVALS IN A WELL VELOCITY SURVEY*

C. W. HORTON†

ABSTRACT

Seismograms obtained in a well survey of the Shell-Longleaf Lumber Co. #1, Vernon Parish, Louisiana, showed well-developed secondary arrivals which satisfied a velocity formula $V=(2000+0.27Z)$ feet per second. If these arrivals are assumed to be transverse waves, a value of 0.43 for Poisson's ratio is obtained. On this same assumption, values of the modulus of rigidity and bulk modulus are computed for various depths. It is shown that the velocity of the secondary wave does not satisfy the equation developed by Lamb for thick-walled tube waves.

A well velocity survey of the Shell-Longleaf Lumber Co. #1, Vernon Parish, Louisiana, was made by the Shell Oil Company, Incorporated. Two shot points at distances of 960 and 1046 feet and approximately 50 feet in depth were used. The seismometer in the well was of the vertical component type with a period of 0.12 seconds and was slightly less than critically damped. The seismometer together with the amplifying channel had maximum response for a frequency of 15 cycles per second. The amount of amplification was held constant for any one record, being varied only with the depth of the well geophone.

The seismograms obtained for geophone depths of 5000 and 5500 feet are shown in Fig. 1. On these records there is a well-developed secondary impetus which it is suggested may be a transverse wave; although the advent of this wave-front is better developed on the seismograms reproduced than on some others, it can be identified with reasonable certainty at several depths. With the exception of the upper 1000 feet of material, the section throughout which the secondary arrivals were observed consisted of Eocene sands and clays.

The possibility that the secondary arrivals are produced by transverse waves is of especial interest, since if this could be established, it would make possible the computation of the elastic constants of unconsolidated clastic sediments, about which very few data are available. For example, no values of the elastic constants for sand or clay are given in the *Handbook of Physical Constants* (Geological Society of America, Special Paper #36).

* Read by title at the thirteenth annual meeting, Fort Worth, Texas, April 7–9, 1943. Manuscript received February 7, 1943.

† Underwater Sound Laboratory, Harvard University, Cambridge, Massachusetts.

In a recent publication Joseph A. Sharpe states,[1] "shear waves to my knowledge have never been observed as a result of firing explosives in a drill hole." Even though it is unlikely that transverse waves are generated at the shot point, there is still no reason why such waves cannot be generated at the base of the weathered layer by the reflection of the longitudinal waves produced at the shot point. L. D. Leet[2] presents records from a well survey on which there is evidence of a secondary compressional wave derived from reflection at the base of

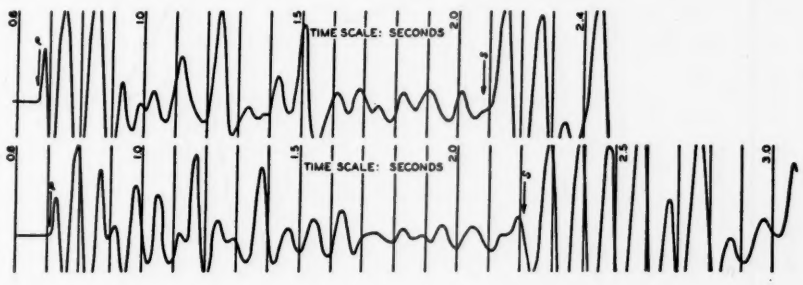


FIG. 1. Tracings of records produced by well geophone. Upper trace: geophone depth 5000 feet; shot depth 55 feet; horizontal distance 1046 feet; charge 10 lbs. Lower trace: geophone depth 5500 feet; shot depth 48 feet; horizontal distance 1046 feet; charge 7.5 lbs.

the weathered layer. If this interpretation is correct, secondary transverse waves must also exist. In what follows it has been assumed that the secondary arrivals of Fig. 1 and of the other records were produced by transverse waves that have their origin at the base of the weathered layer.

The geometry of the arrangement is shown in Fig. 2. Fig. 3 shows that there is a sufficiently large angle of incidence of the longitudinal wave on the base of the weathered layer to generate transverse waves of measurable amplitude. Here are plotted values of the angles made with the vertical by the incident longitudinal waves and the reflected transverse waves which reach various depths in the well: the shot point is taken to be 40 feet below the reflecting interface and 1046 feet from the well. These values are computed for straight line paths and for a value of $\sin i_s = (1870/5650) \sin i_p$. The small divergence of

[1] Joseph A. Sharpe. GEOPHYSICS, Vol. 7, No. 3, p. 311 (1942).
[2] L. D. Leet. Bull. Seis. Soc. Amer., Vol. 27, No. 2, p. 97 (1937).

the reflected transverse wave is significant. For the range of geophone depths of 1000 to 6500 feet throughout which the secondary arrival was observed, incident rays diverging through an angle of 56° give rise to transverse rays that diverge through an angle of only 10°.

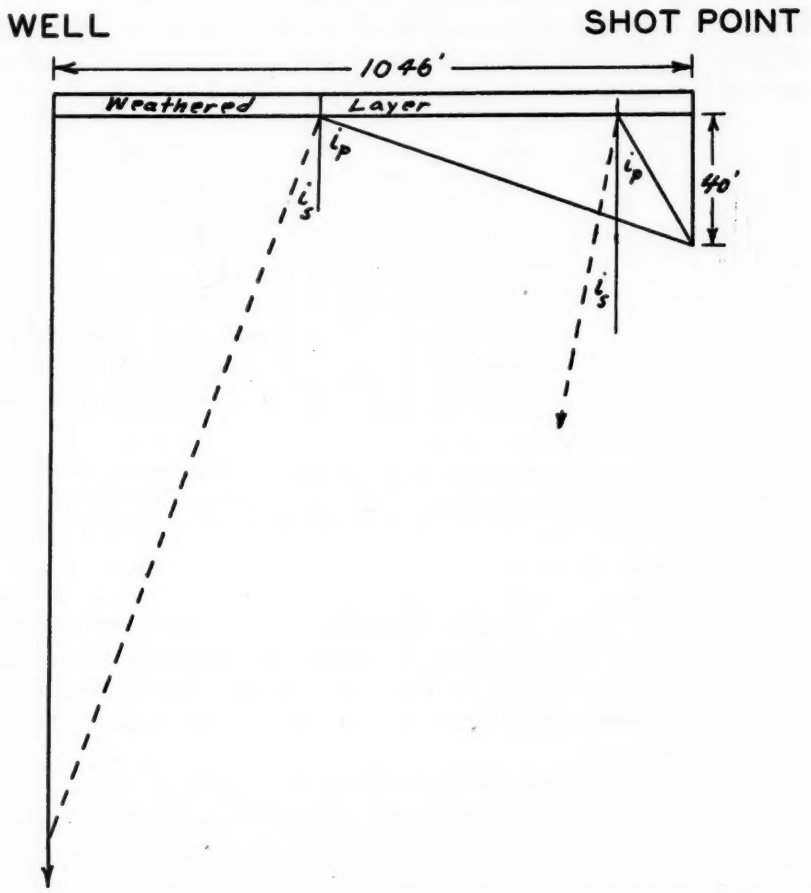


FIG. 2. Geometry of the compressional-transverse waves which are assumed to have caused the secondary arrivals of Fig. 1.

Thus, even if only a small fraction of the amplitude of the incident longitudinal wave is transformed into rotational waves, at large depths the amplitudes will compare favorably because of the relative flatness of the wave front of the rotational waves.

In analyzing the data, the time spent by the incident longitudinal

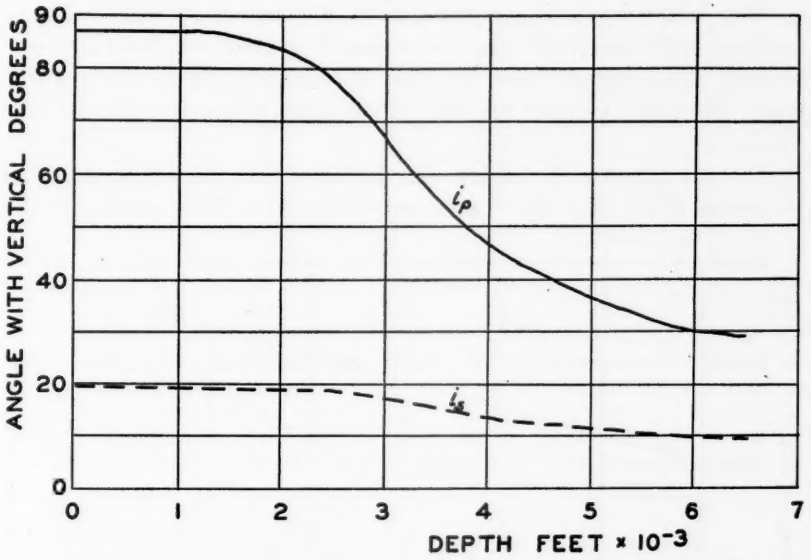


FIG. 3. Computed angles of incidence as a function of depth of well geophone. Solid line: compressional wave. Dashed line: transverse wave.

wave was subtracted from the total travel time and the resultant was corrected to a vertical travel time. Table I gives the depth, vertical travel time, and interval velocity thus obtained.

TABLE I

VERTICAL TRAVEL TIME AND INTERVAL VELOCITY OF TRANSVERSE WAVES*

Depth in Feet	*Vertical Time in Seconds*	*Interval Velocity in Feet per Second*
30	0	
		1660
1000	0.585	
		2980
1500	0.753	
		3010
2000	0.919	
		2250
3000	1.363	
		3420
(3475)	(1.499)	
3500	1.509	
		2940
5000	2.019	
		3400
5500	2.166	
		3800
6500	2.429	

* Origin of transverse waves assumed to be reflection at the base of weathering.

The interval velocity as a function of depth is plotted in Fig. 4 together with the linear approximation $V_s=(2000+0.27Z)$ feet per second. The interval 3000 to 3500 feet which yields the slightly larger value of 3420 feet per second contains 318 feet of Cane River Marl.

For the purpose of comparison, the data have been computed for the assumption that the transverse waves have their origin at the

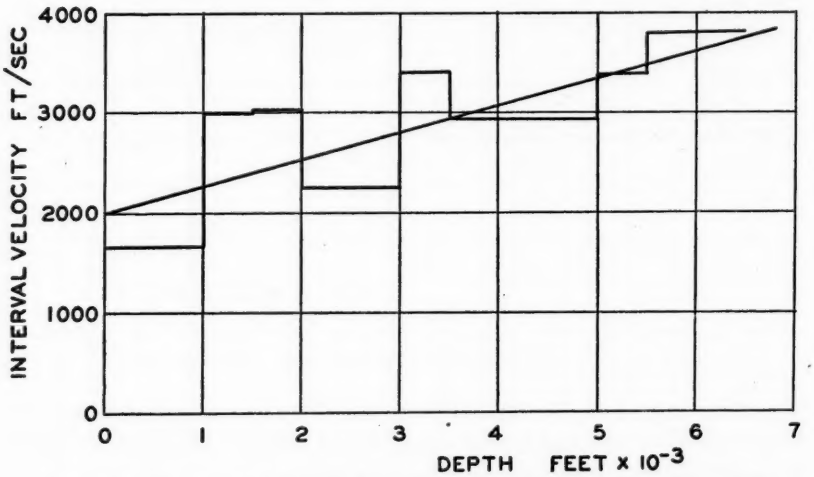


FIG. 4. Interval velocity of secondary arrival, assuming it to be a transverse wave derived from reflection of a compressional wave at the base of the weathered layer. The straight line is the velocity $V_s=(2000+0.27Z)$.

shot point. The resulting vertical times and interval velocities are shown in Table II. For depths below 2000 feet the corresponding velocities are very nearly equal.

If values of the velocity of the longitudinal wave, V_p, and the density, ρ, are also known, the elastic constants may be computed by means of the following equations:

Poisson's ratio:

$$\sigma = (V_p^2 - 2V_s^2)/2(V_p^2 - V_s^2)$$

Modulus of rigidity:

$$\mu = \rho V_s^2$$

Bulk modulus:

$$\kappa = \rho(V_p^2 - \frac{4}{3}V_s^2)$$

TABLE II

VERTICAL TRAVEL TIME AND INTERVAL VELOCITY OF TRANSVERSE WAVES*

Depth in Feet	*Vertical Time in Seconds*	*Interval Velocity in Feet per Second*
30	0	
		1940
1000	0.499	
		2260
1500	0.720	
		2580
2000	0.914	
		2230
3000	1.362	
		3290
(3475)	(1.513)	
3500	1.514	
		2930
5000	2.025	
		3400
5500	2.172	
		3820
6500	2.434	

* Origin of transverse waves assumed to be the shot point.

Table III lists the values of these elastic constants for various depths. The computations are based on the approximate value $V_p=(5650+0.8Z)$ feet per second and the relationship between density and depth given by L. L. Nettleton.[3] $V_s=(2000+0.27Z)$ feet per second is used in computing the elastic constants.

TABLE III

COMPUTED ELASTIC CONSTANTS FOR CENOZOIC SEDIMENTS PENETRATED BY SHELL-LONGLEAF LUMBER CO. NO. 1

Z feet	ρ gms-cm^{-3}	σ	μ dyne-cm^{-2}	κ dyne-cm^{-2}
0	1.90	0.43	0.71×10^{10}	4.69×10^{10}
1000	2.10	0.43	1.01	6.78
2000	2.20	0.43	1.32	8.99
3000	2.25	0.43	1.65	11.3
4000	2.28	0.43	2.01	13.9
5000	2.30	0.43	2.40	16.7
6000	2.32	0.43	2.82	19.8
7000	2.34	0.43	3.29	23.1

Sharpe[4] exhibits in Fig. 6 some records that show secondary arrivals of energy which he attributes to a wave travelling in the fluid of the drill hole. The secondary impetus has "the same form as the pri-

[3] L. L. Nettleton. Fig. 1, A.A.P.G. Bulletin, Vol. 18, No. 9, p. 1179 (1934).
[4] *Op. cit.*, p. 319.

mary motion, but with its phase inverted, and has about the same amplitude as the primary motion." The different character of the secondary arrivals here discussed (Fig. 1) is considered to be partial evidence of the different nature of the two wave motions.

Sharpe cites the following approximate relationship developed by H. Lamb for the velocity of a thick-walled tube wave:

$$\frac{1}{V_T^2} = \frac{1}{\rho_L V_L^2} + \frac{3}{\rho V^2}$$

where ρ_L, V_L = density, velocity of the liquid in the tube,
ρ, V = density, velocity of the medium surrounding the tube,
V_T = velocity of the tube wave.

He solves this equation for ρ and finds a value which is in reasonable agreement with its known value. If this is done with the data here presented, one finds the values $\rho = 0.46$ for $Z = 0$, and $\rho = 0.90$ for $Z = 6000$ feet. ρ_L was taken as 1.6, the estimated density of the drilling mud, and $V_L = 3700$ feet per second. In view of the unreasonable values of ρ derived from this assumption, it seems unlikely that the secondary arrivals of Fig. 1 are thick-walled tube waves.

It is not possible to determine from the evidence available whether the secondary arrivals treated in this paper are transverse waves originating from reflection of compressional waves at the base of the weathered layer or whether they are transverse waves originating at the shot point, but computations based on the premise that they are the former yield plausible values for the elastic constants and for the variation of these quantities with depth.

The author is indebted to Shell Oil Company, Incorporated, for permission to publish the well shooting data which are the basis of this paper.

SELECTION OF COMPUTATIONAL METHODS FOR SEISMIC PATHS*

E. D. ALCOCK†

ABSTRACT

Due to the decrease in magnitude of structures being sought in seismic exploration, the selection of the most accurate method of computation assumes increasing significance. The underlying assumptions and characteristics of several common computational methods are discussed and an analysis is made for a specific case.

INTRODUCTION

The fundamental problem in reflection seismic exploration is to relate the surface data as measured by the instruments to subsurface conditions. The available surface data are: the geometry of the recording set up, total reflection time, reflection "stepout" times, and weathering data. In order to relate these surface data to subsurface conditions, it becomes necessary to make various assumptions regarding velocity conditions and paths taken by the seismic impulses. It is the number and nature of these assumptions which differentiate the various computational methods. The problem of the interpreter is to select the computational method which, with a reasonable expenditure of time and labor, gives the greatest accuracy within the limits of error inherent in the measurements. In the early days of seismic exploration, the method of computation was not so important since the magnitude of the structures being sought was large enough to be revealed by any of the accepted computing methods. At the present time, however, it appears that in the regions being investigated most of the larger features have been found, and it is necessary to look for the small structures; hence, it is highly important that considerable thought be given to the accuracy of the computing method.

It is the purpose of this paper to discuss the implied assumptions and characteristics of several common methods of computation and to analyze a specific case.

ASSUMPTIONS

1. The assumption is made that there is a direct correlation between velocity discontinuities and geologic strata. This assumption is universal in all seismic work, since without it seismic data would

* Presented at the annual meeting, Fort Worth, Texas, April 1943.

† National Geophysical Company, Dallas, Texas.

have no value in the geologic interpretation of the subsurface. There may be special cases where this assumption breaks down; however, practical experience has shown that in general it is valid.

2. The assumption is made that a velocity distribution with depth is the same over an area. This is not as general an assumption in seismic work as No. 1. There are several cases where it has been found invalid. In these cases, as for example in California, it has been necessary to subdivide an area into small blocks within which the assumption is valid and to determine and apply the proper velocity distribution to each block, or by some other means, reconcile departures from this assumption.

3. Before any computational method can be developed, it is necessary to make an assumption as to the attitudes of the velocity zones between the point of origin and the reflecting horizon. It is common practice to make one of the three following assumptions:

a. It is assumed that the velocity zones are all horizontal.
b. It is assumed that the velocity zones are all parallel to the reflecting horizon.
c. It is assumed that the velocity zones at the surface are horizontal and dip at a rate which varies as a function of the depth.

The assumption as to the attitude of the velocity zones is critical since there is a large variation in the results computed from the same surface measurements by the various methods based on these assumptions. Assumption (3a) is the one commonly assumed by most of the so called "curved path" methods. It should be noted that this is a peculiar set of conditions and one which we would not expect to encounter very often in nature. These conditions are really implied by assumption No. 2. However, changes in the velocity distribution with depth due to the attitude of the velocity layers is generally small, and we are reasonably accurate in assuming No. 2 to be valid even though assumption (3a) does not hold. There are special cases in which this is not true, and it is necessary to modify assumption No. 2. Assumption (3a) is one that leads to a category of computational methods which, while not too simple, are at least practical. Assumption (3b) is one which is also possible in nature but is not often found. This assumption, however, leads to a very simple method of computation, and is of use in some instances. Assumption (3c) is probably the one which most accurately fits the conditions generally found in nature. It is possible to assume a function of the dip with depth and derive a computational method. Such a method, however, would be compli-

cated and laborious to derive and use. There are simple methods in common use which, while not rigorous, approximate the results of a method based on this assumption.

4. It is assumed that the paths of the seismic wave are straight lines. This is an assumption which greatly simplifies the computational procedure, and hence is in general use. This assumption is only valid, however, when assumption (3b) holds, since in all other cases the seismic paths will have some curvature. It is a fact, however, that the simple methods of computation based on this assumption, often approximate the true results more accurately than more complicated methods of computation.

There are other fundamental assumptions which are used in the theory of seismic exploration; however, they will not be discussed here since they are common to all methods of computation.

PATH COMPUTATIONS

Let us now classify the various methods of computing seismic wave paths according to the assumptions involved.

Path 1. Assumptions 1, 2, and 3a are assumed valid. From this basis we are able to derive the category of curved path computations (see Fig. 1-B). Several papers[1] have been published on methods of computing depths, horizontal displacements of reflecting points, and angles of dip of the subsurface reflecting horizons, based upon techniques which take into account the curvature of the wave paths introduced by the variation of velocity with depth. In some cases the solutions are based upon algebraic representations of the velocity distribution with depth which are sufficiently accurate for practical purposes, but which, nevertheless, are simple enough in mathematical form to lead to path equations which readily can be integrated. Other methods rely upon graphical or numerical solutions, based upon empirical velocity data, and no mathematical equation is assumed for the velocity distribution with depth. In a recent paper in GEOPHYSICS, Mr. K. H. Waters (*loc. cit.*) has shown how it is possible to construct curves from well shooting data which can be used directly to compute seismic data from steeply dipping beds in an area over which the velocity information may be assumed to apply. It is this method which was employed to compute the curved paths in this paper.

[1] M. Mott Smith, GEOPHYSICS, Vol. IV, No. 1, (1939), p. 8; M. B. Widess and N. A. Haskell, *ibid.*, Vol. V, No. 2 (1940), p. 156; K. H. Waters, *ibid.*, Vol. VI, No. 1 (1941), p. 64; R. A. Peterson, *ibid.*, Vol. VI, No. 1 (1941), p. 74.

The curved path computation based on the assumption of horizontal velocity zones will give a maximum value for the dip of the reflecting horizons, a maximum value for the horizontal displacement of the reflecting point, and a minimum value for the depth of the reflecting point in areas where the section is seismically conformable. An area is *seismically conformable* when the derivative of the function

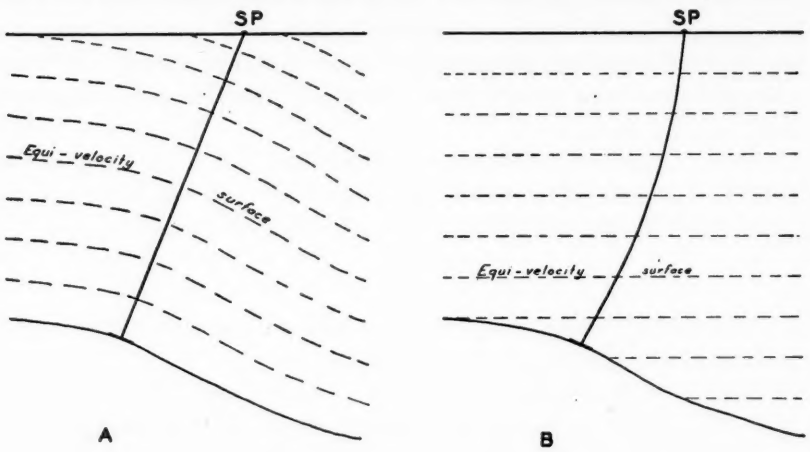


FIG. 1. Equi-velocity surfaces parallel to the reflecting horizon, which are assumed in computing Path 3, are illustrated in A. Horizontal equi-velocity surfaces, which are assumed in computing Path 1 and Path 2, are illustrated in B.

of the dip of the velocity zones with depth is always positive, where the direction of dip of the reflecting horizon is taken as positive. In unconformable sections this is no longer true, and almost anything can happen—depending on the number and degree of unconformities present.

The objective of the "curved path" computation is to provide more accurate subsurface measurements in those regions wherein the variation of velocity with depth introduces curved paths which depart appreciably from the straight paths usually assumed for seismic computations. It should not be assumed that in all areas where velocity distribution induces large departures from straight paths that this objective will be attained.

Path 2. Assumptions 1, 2, 3a, and 4 are assumed valid. From this basis we are able to derive the straight path computation where the interval velocity at the reflecting horizon is used to determine the angle of dip. This computation method is seldom used for dip shooting

since the computed location of the reflecting point differs greatly from the location as determined by other methods. These assumptions, however, are similar to those which form the basis of a common method of computing continuous profiles and in areas where it is necessary to modify the map and correct for displacements due to dip, considerable error will be introduced by the straight path assumption.

Path 3. Assumptions 1, 2, 3b, or 1, 2, 3b and 4 are assumed valid. This is the special case where the curved path is a straight line with the surface velocity being used to determine the angle of dip of the reflecting horizon. (See Fig. 1-A.) In general, these conditions would be encountered very rarely in nature, but might be approximated frequently. In seismically conformable sections, the computed results would give minimum values for the dip of the reflecting horizon and horizontal displacement of the reflecting point and a maximum value for the depth of the reflecting point.

Path 4. Assumptions 1, 2, 3c and 4 are assumed valid. These assumptions form the basis for the reasoning behind the straight path computation, using the average velocity to determine the angle of dip of the reflecting horizon. This method of computation, while generally used, is only an attempt to approximate the true conditions, and in many cases the degree of approximation is poor, while in others it is very accurate. As a rule, an exact solution based on these assumptions is too complicated and laborious to use in common practice.

GENERAL CONSIDERATIONS

Paths 1 and 3 are paths which have physical significance in that they represent actual paths taken by seismic waves under conditions which are possible in nature. The mere fact, however, that these paths possess physical significance does not give them an *a priori* advantage over the other paths, in accuracy of computed results.

In seismically conformable sections paths 1 and 3 represent extremes between which lies the actual path taken by the seismic wave. Where other paths, although possessing no physical significance, fall between these extreme paths, it is possible for them to give more accurate results than paths 1 or 3.

It is also true that there is a certain amount of error inherent in the measurement of the surface data. Where the results computed by different methods do not differ by more than the amount which could be produced by the error in the measurements, we are not justified in unnecessarily complicating our computational procedure.

EXAMPLE

In order to illustrate the analytical procedure a typical area was selected. The whole results of this analysis are based upon direct velocity measurements made at a well in the vicinity. This "well shooting" data is known to be typical of the region and shows a large change in interval velocity through the section. At a depth of 8850 feet the interval velocity is nearly 15,200 feet per second, while near the surface the velocity is approximately 6500 feet per second. The zone of interest lies at a depth of approximately 8000 feet. It is known that the surface beds are nearly horizontal and that the dip of the beds increase uniformly with depth. This is an area in which the increase of velocity with depth is large, and hence the actual seismic path would not approximate a straight line.

Hasty reasoning at this point might lead to the conclusion that the curved path method would give the most accurate results. This is not always the case and it is necessary to make a further analysis by actually computing the results by several methods.

Using a total reflection time T_r of 1.70 sec. and various values of $\Delta T/X$, where ΔT is the "stepout" time and X is the spread length, results have been computed for the various paths 1, 2, 3 and 4, and are presented in Table 1 and Figs. 2, 3, 4, and 5.

TABLE I

COMPARATIVE COMPUTED DIPS, LATERAL DISPLACEMENTS, AND DEPTHS FOR SEISMIC PATHS BASED ON FIVE DIFFERENT ASSUMPTIONS

$\frac{\Delta T}{X}$	*Path 1*			*Path 2*			*Path 3*			*Path 4*			*Path 5*		
$\times 10^3$	θ	R	Z	θ	R	Z	θ	R	Z	θ	R	Z	θ	R	Z
.0057	5°	560′	8685′	5°	750′	8670′	2° 7′	322′	8709′	3°21′	510′	8690′			
.0114	10°	1100′	8615′	10°	1500′	8515′	4°15′	648′	8691′	6°41′	1010′	8625′			
.0225	20°	2120′	8335′	19° 9′	2708′	8000′	8°25′	1289′	8621′	13° 8′	1960′	8370′			
.0441	40°	3905′	7335′	36°25′	4680′	6335′	16°40′	2609′	8344′	25°29′	3570′	7485′	26°31′	3283′	7760′

θ=angle of dip of reflecting layer, R=horizontal displacement of reflecting point, and Z=depth of reflecting point.

The area is assumed to be seismically conformable, hence, Paths 1 and 3 represent the maximum and minimum limits for the actual path taken by the seismic wave. Path 2 lies outside these limits for all angles and hence, is excluded from consideration. Path 4, however, lies between 1 and 3, and since the velocity conditions do not satisfy exactly all the conditions of either Path 1 or Path 3, a further analysis is necessary.

If we assume a linear increase of the dip of the velocity zones with

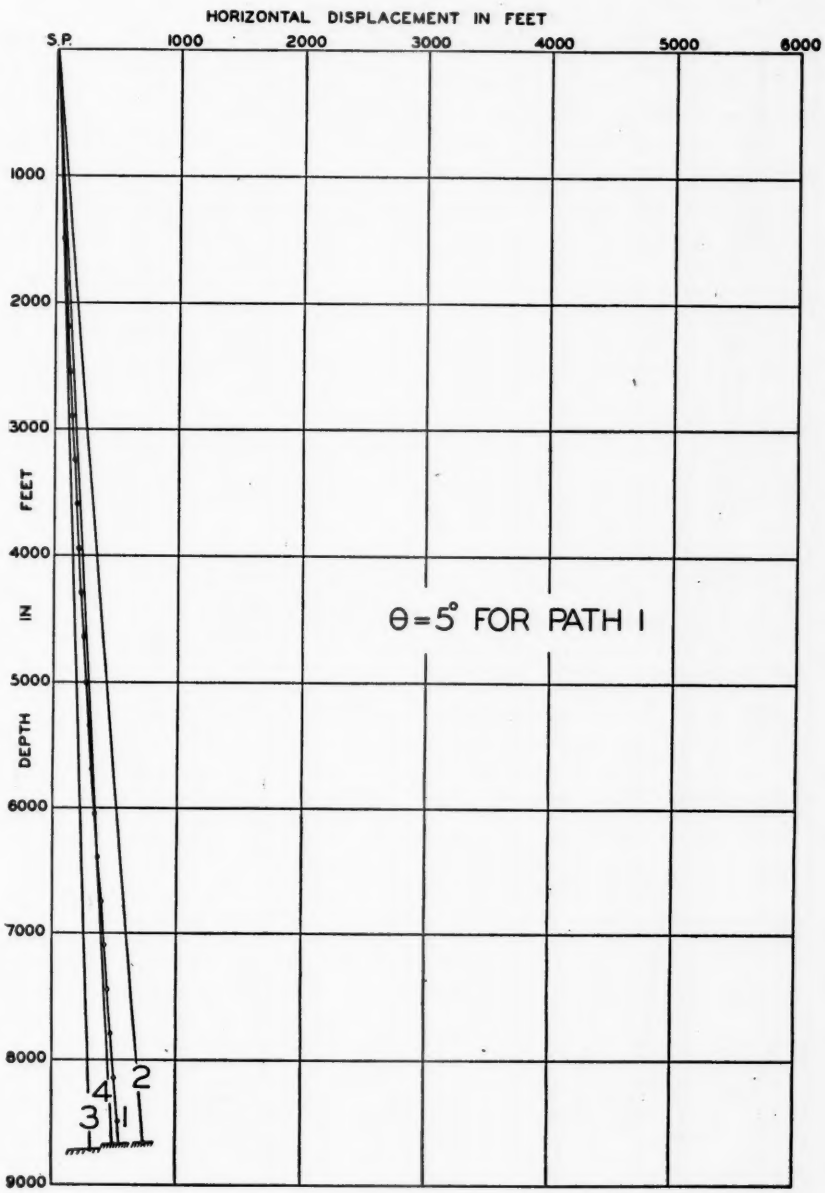


FIG. 2. Paths 1–4 under the assumption that $\Delta T/X$ is 0.0057×10^{-3}, and $\theta = 5°$ for Path 1.

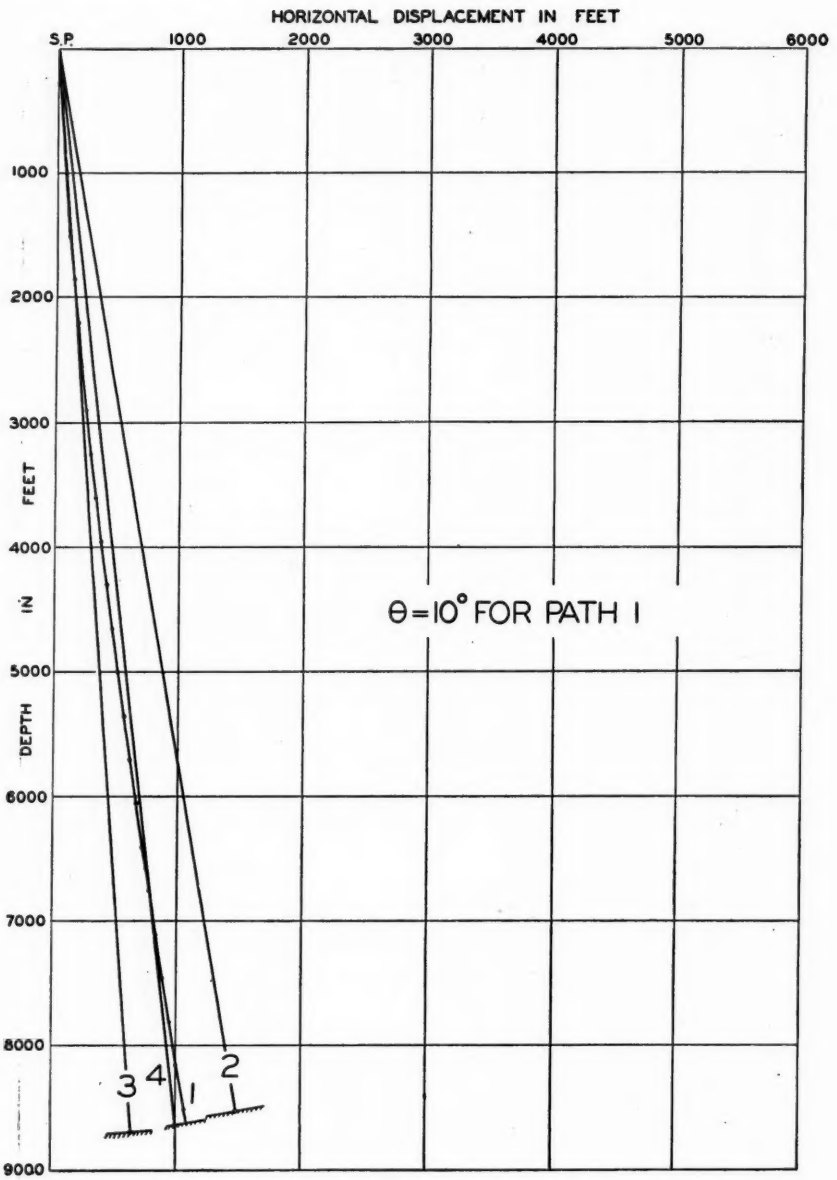


FIG. 3. Paths 1–4 under the assumption that $\Delta T/X$ is 0.114×10^{-3}, and $\theta=10°$ for Path 1.

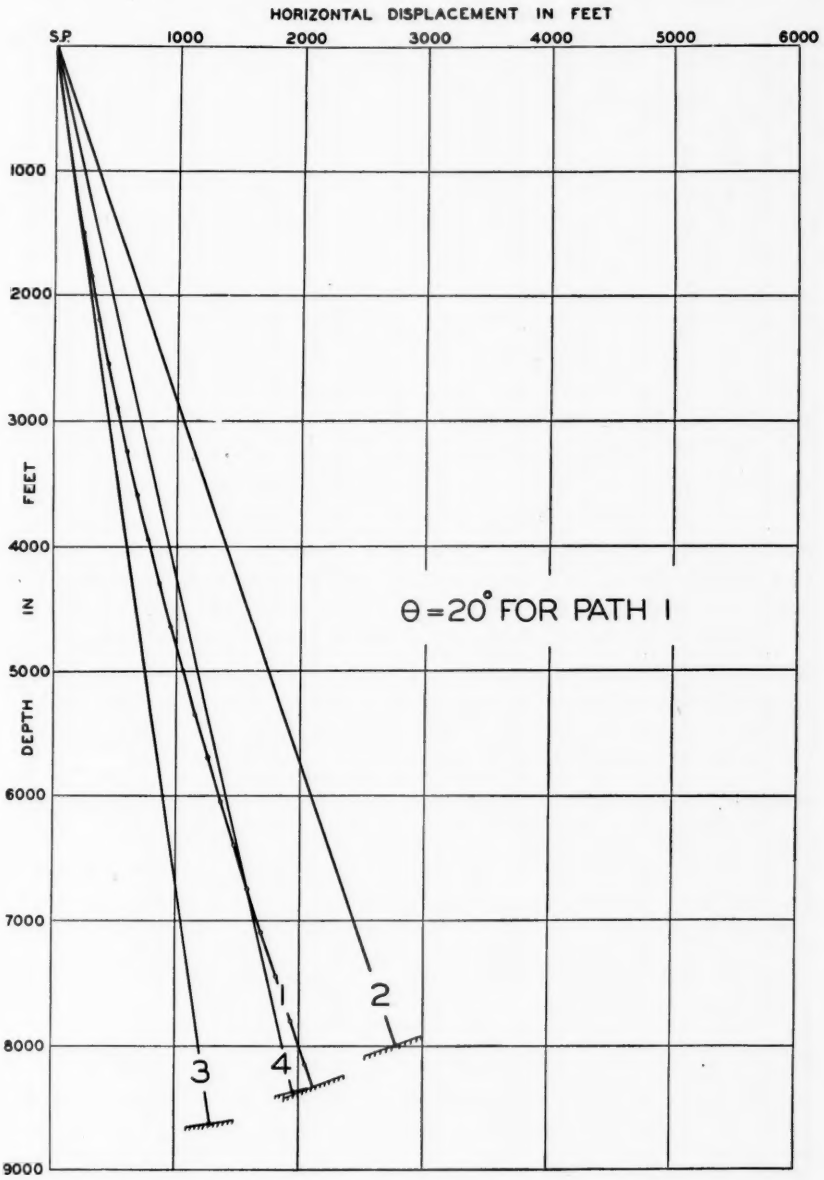


FIG. 4. Paths 1–4 under the assumption that $\Delta T/X$ is 0.0225×10^{-3}, and $\theta = 20°$ for Path 1.

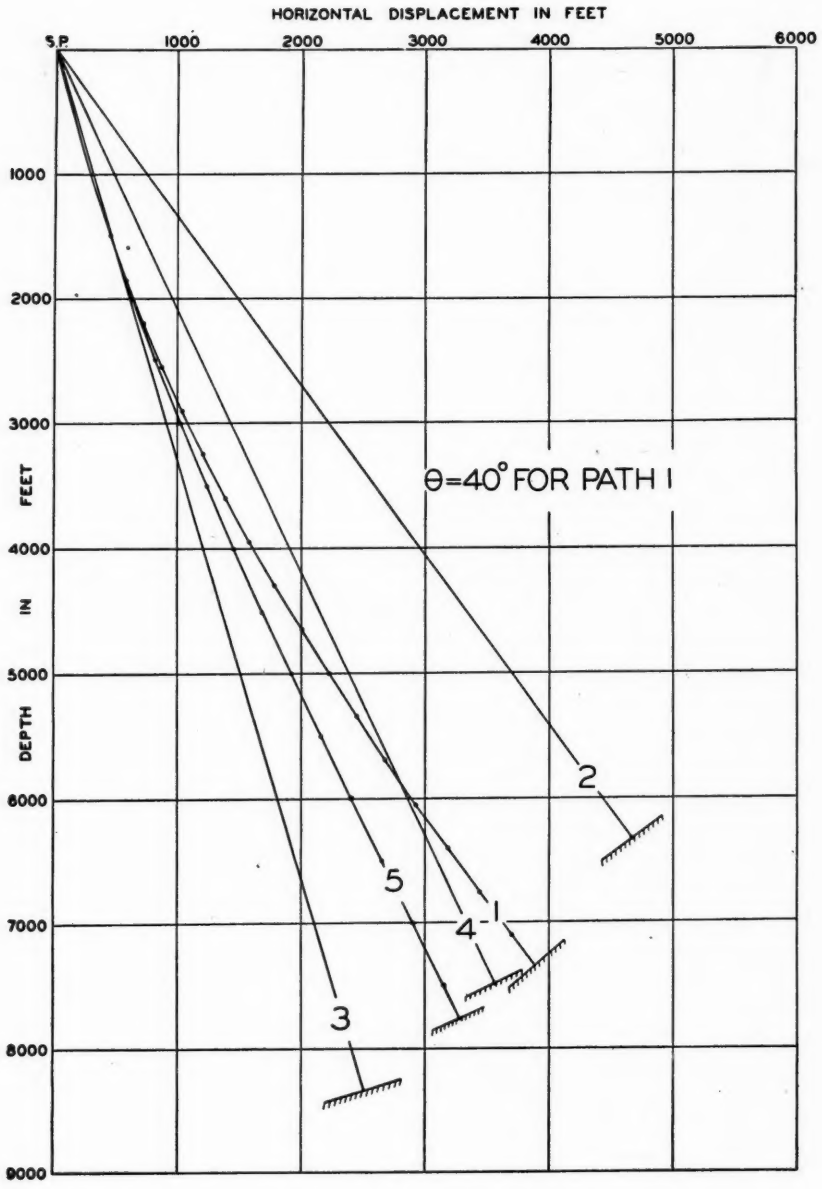


FIG. 5. Paths 1–5 under the assumption that $\Delta T/X$ is 0.0441 and $\theta=40°$ for Path 1.

depth from horizontal at the surface to parallel to the reflecting horizon at the reflection depth, and $\Delta T/X = .0441$, an approximate construction of the seismic path is given by Path 5, Fig. 5. This is admittedly an approximation but is close enough for the purpose of this analysis.

By examination of Table 1 and Fig. 5, we can draw the conclusion that of the commonly used computational methods, Path 4, the straight line path using the average velocity to determine the dip, will probably give us the closest approximation to the true results for this angle of dip. By a comparison of Figs. 2, 3, 4 and 5, it is seen that as the angles decrease, the paths converge. Therefore, if the conclusion is true for this angle, it is also true for smaller angles. Since angles of larger magnitude were not encountered in the area, and since this is one of the simplest computing methods, it was used in the interpretation of the results for this area. It has subsequently proved that the seismic data computed with this method checks reasonably well with the subsurface data obtained by drilling.

CONCLUSION

At the present time when the magnitude of the structures being sought is decreasing, greater care should be exercised in selecting the computational method. Each area should be considered as a separate problem. In general, it is impossible to select a critical angle and make the statement that in all areas for angles less than the critical angle, the divergence in results between several computational procedures will be less than the inherent error in surface measurements, since this divergence also depends upon the function of velocity with depth. A careful analysis should be made in which all the known geological data are considered in relation to the assumptions involved in the various computing methods. Of course, in areas where well data are available, there is little argument but that the proper computing method is the one which gives results jn closest agreement with the known data.

ACKNOWLEDGMENTS

The author is indebted to the National Geophysical Company for permission to publish the results contained in this paper. He has benefited greatly by discussions with Mr. R. D. Arnett, Mr. C. C. Williams, and Mr. K. H. Waters, and has used some data from an unpublished paper by Mr. K. H. Waters and Mr. R. D. Arnett.

REVIEW

Aerial Photographs: Their Use and Interpretation. A. J. Eardley. Harper and Brothers, N. Y. (1942), 200 pp., $2.75.

This book is confined to the presentation of photogrammetric techniques which are necessary in the general use and interpretation of aerial photographs. "Aerial Photographs" has been thoroughly tested by the author in class-room use, and represents the greatly expanded eighth edition of the author's "Interpretation of Geologic Maps and Aerial Photos" which has heretofore been available only in lithoprint form.

The first four chapters of "Aerial Photographs" is devoted to the preparation, use, and reading of aerial photographs covering the limitations, types of photographs and cameras to conform with the size of area and purpose of the survey, and availability; stereoscopic vision, stereoscopic examination, types and methods of improvising stereoscopes, field and stereoscopic methods of contouring vertical photographs, and stereosketching; the manner of matching and assembling aerial photographs into mosaics; and the interpretation of the culture on aerial photographs such as railroads, roads, drainage, and vegetation.

The second part is devoted to the principles of interpreting geologic maps as applied to the interpretation of aerial photographs. For this portion the student is assumed to have had an introductory course in geology and a basic course in structural geology. Chapters V to VIII discuss patterns of outcrops including sections on horizontal beds, inclined beds, determination of strike and dip, thickness of formation and width of outcrop, folding beds, unconformities, faults, igneous rock bodies, procedure for interpreting complex outcrop patterns, and shore lines; photographic guides for tracing contacts based on tone and texture, banding, combinations of beds, characteristics of erosion, patterns of drainage, vegetation, and deceptive markings; the manner of tracing geologic contacts on photographs and the preparation of structure contour maps and cross sections; and oblique aerial photographs for reconnaissance mapping.

The final chapter, on the Tactical Interpretation of Aerial Photographs, utilizes material presented throughout the volume and covers the material in this field which is not confidential, and serves as a working basis for students of military science.

The examples and exercises in the text are constructed around regions for which aerial photographs are available in spite of war-time restrictions; thus the problems solved are actual, not theoretical ones. Some fifty aerial photographs are reproduced in the text with such perfection that they are usable for careful study.

The publications considered of outstanding value on the use and interpretation of aerial photographs are listed in the bibliographies at the end of each chapter. The names and addresses of the various commercial photoflying companies and their respective areas are included, as well as the various Government agencies where aerial photographs are available. In general, references to all equipment and material are quite specific and complete.

This book should serve as a very practical reference and guide to the geologic interpretation of aerial photographs, as well as a class-room text on this subject.

JOHN L. BIBLE

PATENTS*

ELECTRICAL PROSPECTING

U.S. No. 2,314,597. S. R. Phelan. Iss. 3/23/43. App. 12/14/39.

Methods of Making Geophysical Surveys. A method of electrical prospecting using two or more equal current electrodes of like polarity separated by distances of the same order as the distance to the electrode of opposite polarity, and making potential observations on the surface trace of those equipotential surfaces which are relatively flat under the like electrodes.

U.S. No. 2,314,874. H. M. Evjen. Iss. 3/30/43. App. 2/25/42. Assign. Nordel Corporation.

Reversing Switch. A reversing switch for d-c electrical prospecting, operation being by rocking a contactor between sets of contacts having accurately adjustable stops.

U.S. No. 2,314,873. H. M. Evjen. Iss. 3/30/43. App. 9/27/41. Assign. Nordel Corporation.

Apparatus for Making Geophysical Explorations. An apparatus for electrical prospecting by means of d-c reversed at a controlled frequency and using current and potential commutators, the pick-up potential being measured by comparing it with the drop across a resistor in the current circuit by means of a condenser and ballistic galvanometer.

GEOCHEMICAL PROSPECTING

U.S. No. 2,310,291. L. Horvitz. Iss. 2/9/43. App. 9/23/40. Assign. E. E. Rosaire.

Geochemical Prospecting. A method of soil prospecting or well logging in which samples are analysed for *-ous* ions of metals which normally occur in the *-ic* state.

U.S. No. 2,310,318. E. E. Rosaire. Iss. 2/9/43. App. 7/20/40.

Geochemical Prospecting. The preservation of soil samples in surface prospecting or well logging by keeping them refrigerated at temperatures below 0°C to avoid loss of heavy hydrocarbons.

U.S. No. 2,311,151. J. G. Campbell. Iss. 2/16/43. App. 5/10/40. Assign. R. H. Fash, trustee.

Analysis of Soil Samples for Determining Oil Content. A method of soil analysis or well logging in which samples are extracted with ether and the ultraviolet fluorescence of the extract measured, the readings being corrected for measured particle sizes in the original sample in order to compensate for variations in the surface area of the particles.

U.S. No. 2,312,271. R. O. Smith. Iss. 2/23/43. App. 6/22/39.

Method of Locating Subterranean Petroleum Deposits. A method of soil analysis prospecting in which samples are analyzed for adsorbed solid hydrocarbons by extraction with carbon tetrachloride.

* Abstracts by O. F. Ritzmann, Gulf Research & Development Co.

GRAVIMETRIC PROSPECTING

U.S. No. 2,307,917. D. H. Clewell. Iss. 1/12/43. App. 3/6/40. Assign. Socony-Vacuum Oil Co., Inc.

Gravity Meter. A gravity meter having two masses suspended by cantilever springs on opposite sides of a central support and a helical spring connected between the two masses.

U.S. No. 2,311,771. G. Norgaard. Iss. 2/23/43. App. 2/6/39 and 2/8/40. Assign. Aktiebolaget Elektrisk Malmletning.

Apparatus for Measuring Gravity. A gravity meter consisting of two fine quartz rods loaded at their upper ends and deviating slightly from the vertical in opposite directions so that the distance between their upper ends varies with gravity, the entire unit being immersed in a damping fluid.

SEISMOGRAPH PROSPECTING

U.S. No. 2,307,790. H. Hoover, Jr. Iss. 1/12/43. App. 7/26/39. Assign. Consolidated Engineering Corp.

Automatic Amplitude Control System. An AVC system for seismograph amplifiers in which the AVC filter overlaps the amplifier filter only slightly and in which instability is avoided by negative feed back accomplished through change of signal polarity in passing through a tube.

U.S. No. 2,307,791. H. Hoover, Jr. Iss. 1/12/43. App. 7/26/39. Assign. Consolidated Engineering Corp.

Seismic Exploration System. A method of operating a number of seismograph amplifier channels on common batteries by introducing in each element of the circuit a low pass RC decoupling filter to reduce cross-feed between channels.

U.S. No. 2,307,792. H. Hoover, Jr. Iss. 1/12/43. App. 7/28/39. Assign. Consolidated Engineering Corp.

Seismometer. A dynamic type suspended coil geophone having a case flat on one end and dome shaped on the other end, and a reversing switch connected in the line so as to correct the sense of the signal when planted upside down.

U.S. No. 2,309,560. W. R. Welty. Iss. 1/26/43. App. 3/18/40. Assign. Olive S. Petty.

Method and Apparatus for Measuring and Recording Vibrational Effects. Integrating circuits for a seismograph amplifier so that absolute displacement of the ground may be recorded with a short period geophone.

U.S. No. 2,309,817. L. F. Athy and E. V. McCollum. Iss. 2/2/43. App. 8/2/37 and 11/12/40. Assign. Continental Oil Co.

Method of Making Geophysical Explorations. A method of seismograph prospecting in which vertical velocities are determined and a velocity contour map is plotted.

U.S. No. 2,311,079. J. O. Parr. Iss. 2/16/43. App. 3/28/40. Assign. Olive S. Petty.

Transducer. A variable air gap suspended armature reluctance type seismometer having a very light steady mass and having electromagnetic damping.

U.S. No. 2,312,642. A. J. Herzenberg. Iss. 3/2/43. App. 3/29/41. Assign. Shell Development Co.

Seismic Exploration Method. An AVC for seismograph amplifiers in which the control is accomplished by changing the d-c current through a copper oxide rectifier network which shunts the signal.

U. S. No. 2,312,934. E. M. Shook. Iss. 3/2/43. App. 2/1/38. Assign. Socony-Vacuum Oil Co., Inc.

Gain Control for Seismograph Amplifiers. An amplification suppressor and expander which operates as a function of time and is initiated by the shot moment impulse.

U. S. No. 2,313,091. D. S. Renner. Iss. 3/9/43. App. 12/26/39. Assign. Geophysical Service, Inc.

Seismic Recording. A method of photographically marking elapsed time directly on a seismograph record starting from zero at the shot moment by automatically firing the shot as a continuously running timer goes through its zero mark.

U. S. No. 2,313,101. J. Stuart, II. Iss. 3/9/43. App. 1/10/40. Assign. Hercules Powder Co.

Blasting Machine. An electric blasting machine having in the cap circuit a voltage control tube which breaks down only when the output voltage reaches a sufficiently high value and thereafter becomes highly conducting.

WELL LOGGING AND SURVEYING

U. S. No. 2,307,887. C. J. Haynes. Iss. 1/12/43. App. 12/28/39. Assign. Standard Oil Development Co.

Rotating Contact Device. A well logging electrode which makes contact with the sides of the hole by means of sharp wheels urged outward by springs.

U. S. No. 2,308,361. R. E. Fearon. Iss. 1/12/43. App. 11/10/38. Assign. Well Surveys, Inc.

Well Logging Method and Device. A neutron well logging device consisting of a neutron-emitting source and an ionization chamber shielded from direct radiation of the source to measure the scattered radiation from the formations.

U. S. No. 2,309,004. E. H. Olmstead. Iss. 1/19/43. App. 10/28/40. Assign. Well Surveys, Inc.

Well Logging Winch Truck. A truck for handling well logging cable, the cable drum being driven by a hydraulic motor and a variable stroke remote controlled pump connected to the prime mover.

U. S. No. 2,309,835. R. E. Fearon. Iss. 2/2/43. App. 2/14/41. Assign. Well Surveys, Inc.

Well Logging Apparatus and Method Thereof. A combination gamma ray well logging instrument and gun perforator, the former being suspended a short distance below the latter, and both operated over the same cable by using different frequencies for firing the projectiles and recording the gamma ray log.

U. S. No. 2,309,877. D. H. Weinstein and L. H. Metzner. Iss. 2/2/43. App. 1/8/38 and 11/4/41. Assign. Cooperative Development Co.

Device for Determining Inclination of Well Bores. An inclinometer using a series of ball type levels, contact of a ball with the outside edge of a level causing an identifying mechanical signal and the number of signals corresponding to the largest deviation registered.

U. S. No. 2,309,905. E. M. Irwin, B. H. Rule, and G. E. Lewis. Iss. 2/2/42. App. 1/27/39 and 4/29/41. Assign. Cooperative Development Co.

Device for Surveying Well Bores. A well surveying instrument using electrically contacting ball type levels and a gyro compass and fiducial point whose relative positions are detected by a continuously rotating exploring contactor, appropriate electrical impulses being sent to the surface and recorded.

U. S. No. 2,310,611. E. E. Blondeau. Iss. 2/9/43. App. 12/23/38. Assign. Geophysical Research Corp.

Electrical Exploration of Geological Strata. A method of electric well logging without electric cable and using a current source in the well, one current electrode being either the drill bit or at the lower end of an uninsulated cable and the other current electrode being the drill stem or cable itself, potential recording electrodes both being on the surface.

U. S. No. 2,311,757, J. J. Jakosky. Iss. 2/23/43. App. 2/25/38. Assign. Schlumberger Well Surveying Corp.

Thermometric Method and Apparatus for Exploration of Boreholes. A method of well logging in which a heating device and one or more recording thermometers separated some distance from the heater are simultaneously moved in the well, the temperatures being influenced by the thermal diffusivity of the formations.

U. S. No. 2,313,168. W. J. Opocensky. Iss. 3/9/43. App. 4/25/40. Assign. Eastman Oil Well Survey Company.

Inclination and Directional Device for Boreholes. A device which at intervals photographs the position of a clock, a magnetic compass and a special type of direct reading and direct indicating plumb bob.

U. S. No. 2,313,310. J. C. Arnold. Iss. 3/9/43. App. 8/4/40. Assign. Lane-Wells Co.

Well Bore Radiation Logging Apparatus. A radiation logging apparatus in which the discharge rate of a periodically charged electroscope is photographed, the entire sequence of operations occurring automatically in the apparatus and signalling the completion of the cycle to the surface over a single conductor.

U. S. No. 2,313,384. R. E. Lee. Iss. 3/9/42. App. 4/28/39. Assign. J. H. Reynolds.

Means for Determining the Tectonics and Nature of Subsurface Geology. A device for making an electric well log and a temperature log either while drilling or as a separate operation.

U. S. No. 2,315,127. W. D. Mounce. Iss. 3/30/43. App. 10/12/39. Assign. Standard Oil Development Co.

Resistance Thermometer. A resistance thermometer for temperature logging, the resistance element being in one arm of a bridge fed by a-c over a single conductor cable, indication being obtained by rectifying the a-c bridge unbalance and feeding the d-c to the surface over the same conductor.

U. S. No. 2,315,355. S. A. Scherbatskoy. Iss. 3/30/43. App. 4/30/40. Assign. Well Surveys, Inc.

Well Surveying Method and Apparatus. A method of radioactivity logging without removing the drill stem which consists in lowering a radiation detector through the drill stem.

MISCELLANEOUS

U. S. No. 2,307,729. J. L. Foster. Iss. 1/5/43. App. 3/17/39.

Well Explosive. Treating a well for increased recovery by firing an explosive projectile with a time fuse into the side wall.

U. S. No. 2,308,006. R. E. Hendrickson. Iss. 1/12/43. App. 8/4/41. Assign. Lane-Wells Co.

Perforation Burr Elimination. A plug of soft metal placed ahead of a gun perforator bullet to eliminate burr on the inside of the well casing.

U. S. No. 2,308,156. J. S. Crump. Iss. 1/12/43. App. 8/29/40. Assign. Standard Oil Development Co.

Borehole Sampler. A bottom hole sampling device for operation on a wire line, the chamber being opened by a jerk of the line and closed by a check valve on removal from the hole.

U. S. No. 2,308,176. L. G. Howell. Iss. 1/12/43. App. 2/1/41. Assign. Standard Oil Development Co.

Operations in Boreholes. In cementing jobs requiring different batches of cement, mixing with each batch a short-lived radioactive material of different half-life and subsequently repeatedly running radioactivity logs to determine the location of each batch of cement.

U. S. No. 2,308,390. O. F. Ritzmann. Iss. 1/12/43. App. 12/9/40. Assign. Gulf Research & Development Co.

Apparatus for Detecting and Exhibiting Explosions in Wells. An apparatus for detecting when a well shot fires by picking up the resulting ground vibration with a seismograph geophone connected to an amplifier having a background noise indicator and a tripping device to indicate that the shot has fired.

U. S. No. 2,308,860. M. S. Clark. Iss. 1/19/43. App. 11/23/40.

Means for Drilling Rock, Concrete, and the Like. Apparatus for drilling into non-conducting material by the application of an electric arc whose heat causes spalling off of material from the bottom of the hole.

U. S. No. 2,310,213. J. A. Buchanan, U.S.N. Iss. 2/9/43. App. 11/1/41.

Angular Classifying Accelerometer. An angular accelerometer of the classifying type in which the mass is pivoted through its center of mass and in which electrical contacts are opened or closed when the angular acceleration exceeds certain limits imposed by a spring.

U. S. No. 2,310,559. C. P. Walker. Iss. 2/9/43. App. 9/18/37.

Vibration Translating Means. A condenser microphone for use on an echo well sounding device and circuits for utilizing the condenser microphone for recording echoes from obstructions in the well.

U. S. No. 2,311,312. H. N. Marsh. Iss. 2/16/43. App. 2/17/41. Assign. Socony-Vacuum Oil Co., Inc.

Continuous Mud Weight Indicator. A device for continuously indicating or recording mud weight by passing part of the mud stream through a straight pipe hinged at the intake end and open at the discharge end, the open end being connected to a weight indicator.

U. S. No. 2,311,416. O. G. Salb and R. E. Sturm. Iss. 2/16/43. App. 7/17/39 and 1/6/41.

Pickup for Detecting and Translating Vibrations. A permanent magnet moving coil type dynamic contact microphone for use as an electric stethoscope.

U. S. No. 2,311,637. J. A. Buchanan, U.S.N. Iss. 2/23/43. App. 10/3/41.

Accelerometer. A multiple unit classifying accelerometer using a cantilever spring and an internally damped mass and indicating by making or breaking an electrical contact.

U. S. No. 2,312,234. J. P. Brandt. Iss. 2/23/43. App. 10/31/40. Assign. Shell Development Co.

Acceleration Responsive Device. A device for shutting down the prime mover at a pumping rig when sucker rod failure occurs, the resulting excessive acceleration moving a mass normally resting between two blocks into a position whereby it completes an electrical shut down circuit.

U. S. No. 2,312,805. L. A. Douglas. Iss. 3/2/43. App. 6/19/41.

Means for Laterally Entering Subterranean Strata and Withdrawing the Pore Content Thereof.

A side wall coring device which is run down inside the drill pipe, the core cutter being forced into the formation by weight applied on the drill pipe, and a vacuum chamber for extracting and retaining the fluid from the formation pores.

U. S. No. 2,313,176. P. P. Shelby. Iss. 3/9/43. App. 7/19/40.

Well Tester. A formation pressure measuring device consisting of cups which may be forced against the perforated casing by an electromagnet, the interior of the cups being connected by a conduit to pressure measuring apparatus at the surface.

U. S. No. 2,313,369. L. Spencer. Iss. 3/9/43. App. 2/28/40. Assign. Lane Wells Company.

Formation Tester. A gun perforator which may be held against the casing at the point of perforation and arranged to collect samples of the formation and its production at that point.

U. S. No. 2,313,806. W. J. Crites. Iss. 3/16/43. App. 3/24/41. Assign. Phillips Petroleum Co.

Coring Apparatus. A coring device in which the drill stem is connected to the casing and the core cutter is connected to the rotor of a fluid pump, differential motion of the pump permitting circulation of fluid proportional to the hardness of the formation.

U. S. No. 2,313,978. A. H. Toepfer. Iss. 3/16/43. App. 4/24/40. Assign. Westinghouse Electric & Manufacturing Co.

Oscillograph Viewing Device. An arrangement for viewing two cathode ray oscilloscope screens simultaneously, either by combining them into a stereoscopic eyepiece, or by focusing images of a number of screens on a ground glass.

U. S. Nos. 2,314,540. R. L. Huntington. Iss. 3/23/43. App. 12/30/41. Assign. Phillips Petroleum Company.

Apparatus for Measuring Volume of Bottom Hole Portion of Well Bores. A device for measuring the volume of a cavity at the bottom of a hole by blowing up an elastic bag in the cavity and measuring the pressure, volume, and temperature of the gas used.

PUBLICATIONS RECEIVED

(The publications listed below were received since issuance of GEOPHYSICS, Vol. VIII, No. 2 (April, 1943), and are available for loan to the membership. Articles cited are those considered of particular interest to geophysicists.)

American Journal of Science, Vols. XXXV, XXXVI (Fifth Series), 1938; Vol. 238, 1940, "The Thermal Conductivity of Rocks and Its Dependence upon Temperature and Composition," by Francis Birch and Harry Clark, Nos. 8, 9 (August, September), pp. 529–558, 613–635; Vol. 239, 1941, "The Thermal State of the Earth," by Harold Jeffreys, No. 11 (November), pp. 825–835; Vol. 241, No. 2 (February, 1943), "A Method of Determination of the Direction of the Magnetic Field of the Earth in Geological Epochs," by Elliot T. Benedikt, pp. 124–129; No. 3 (March, 1943), (New Haven).

Economic Geology, Vol. XXXVIII, No. 2 (March–April, 1943), (Lancaster).

Experiment Station Hydraulics Bulletin, The, Vol. 5, No. 1 (October, 1942), (Vicksburg. Miss.).

Geophysical Investigations in the Tri-State Zinc and Lead Mining District, by J. J. Jakosky, R. M. Dreyer, and C. H. Wilson, December, 1942 (Topeka, Kans.).

Independent Petroleum Association of America Monthly, The, Vol. XIII, Nos. 11, 12 (March, April, 1943); Vol. XIV, No. 1 (May, 1943), (Tulsa).

Journal of the Institute of Petroleum, Vol. 28, No. 228 (December, 1942), Vol. 29, No. 230 (February, 1943), "Compaction and Some Oilfield Features," by G. D. Hobson, pp. 37–54; Nos. 231, 232 (March, April), (Bungay, Suffolk, England).

Journal of Applied Physics, Vol. 14, Nos. 2, 3, 4 (February–April, 1943), (Lancaster).

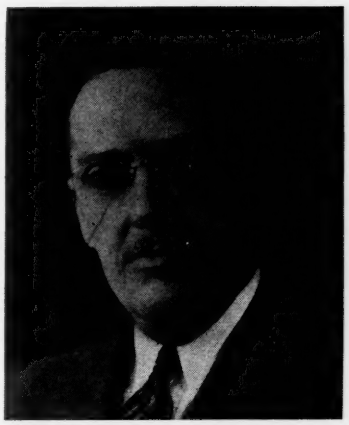
Petroleum, Vol. VI, No. 2 (February, 1943), "Geophysical Prospecting in Poland," pp. 21–22; Nos. 3, 4 (March, April), (London).

Review of Scientific Instruments, The, Vol. 14, Nos. 2, 3, 4 (February–April, 1943), (Lancaster).

World Petroleum, Vol. 14, No. 3 (March, 1943), "War Demands and Exploration," by E. L. DeGolyer, pp. 26–28; "Geochemistry and Future Exploration," by Robert O. Smith, pp. 45–47, 49; "Accelerated Discovery through Geophysics, by L. I. Freeman, pp. 48–49; "Wildcatting and Oil Reserves," by Frederic H. Lahee, pp. 30–31; Nos. 4, 5 (April, May), (New York).

CONTRIBUTORS

BENJAMIN B. WEATHERBY received his A.B. and A.M. degrees from Haverford College, and his Ph.D. from the University of Pennsylvania. He taught physics at Lafayette, University of Toledo, and the University of Pennsylvania. Dr. Weatherby's association with the Amerada Petroleum Corporation and the Geophysical Research Corporation began in 1925 when he was a party chief for GRC, and has continued to date, with the exception of a two year absence spent in teaching and study. He is now president of the Geophysical Research Corporation, and a vice-president and director of the Amerada Petroleum Corporation. Dr. Weatherby is a member of the American Physical Society, American Institute of Mining and Metallurgical Engineers, American Geophysical Union, American Association of Petroleum Geologists (Associate Editor 1932), and the Society of Exploration Geophysicists (Editor, 1934, President, 1935).



BENJAMIN B. WEATHERBY

H. G. PATRICK

H. G. PATRICK received his B.S. degree in Electrical Engineering from The Rice Institute in 1925. Immediately following graduation he entered the Geophysics Department of the Humble Oil and Refining Company by whom he is still employed. Since 1934 he has been in charge of seismic exploration for that company. He is a member of the Society of Exploration Geophysicists.

W. A. SEYFFERT

WILLIS A. SEYFFERT has been employed by E. I. du Pont de Nemours for 27 years, as a salesman, explosives technician, and assistant district manager. He is an associate member of the Society of Exploration Geophysicists.

C. W. HORTON received his B.A. degree in 1935 and his M.A. degree in 1936 from The Rice Institute. Except for one year (1937–1938) in the graduate college of Princeton University, he has worked for the Shell Oil Company, Inc., from 1936 to January 1943. His work with Shell was in the fields of seismograph and electrical interpretation. He is at present a Special Research Associate with the Underwater Sound Laboratory at Harvard University.

MR. HORTON is a member of the Society of Exploration Geophysicists and the Seismological Society of America.

C. W. HORTON

Photographs and biographies of contributors to this issue not appearing above have appeared previously, as follows:

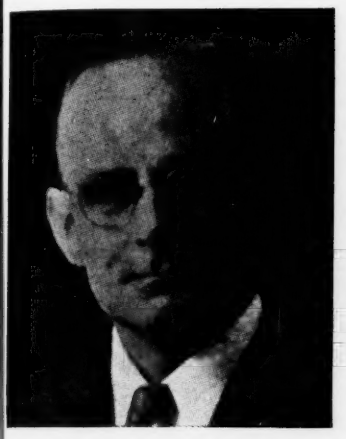
F. GOLDSTONE. Vol. VII, No. 1, p. 108 (January 1942), and No. 3, p. 330 (July 1942).

E. D. ALCOCK. Vol. VII, No. 4, p. 426 (October 1942).

W. T. BORN. Vol. VI, No. 3, p. 302 (October 1941).

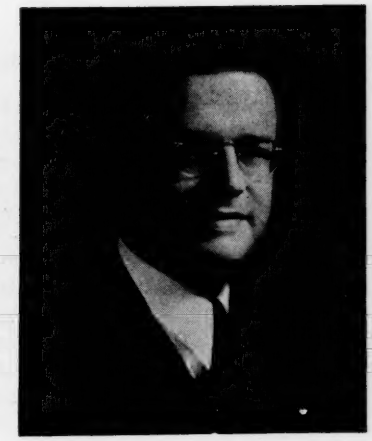
PAUL WEAVER. Vol. VII, No. 3, p. 329 (July 1942).

OFFICERS FOR THE YEAR ENDING APRIL 1944



F. GOLDSTONE, Past President
Chief Geophysicist,
Shell Oil Company, Inc.,
Houston, Texas

R. D. WYCKOFF, President
Staff Geophysicist,
Gulf Research and Development Co.,
Pittsburgh, Pennsylvania



W. M. RUST, JR., Vice-President
Supervisor of Geophysical Research,
Humble Oil and Refining Company,
Houston, Texas

HART BROWN, Secretary-Treasurer, President
Brown Geophysical Company,
Houston, Texas

JOSEPH A. SHARPE, Editor
Chief Physicist,
Stanolind Oil and Gas Company,
Tulsa, Oklahoma

THE SOCIETY ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following candidates for membership in the Society. This publication does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it to the Secretary within thirty days. (Names of sponsors are placed beneath the name of each nominee.)

ACTIVE

Chester Franklin Barnes
J. E. LaRue, Dave P. Carlton, H. W. Merritt

Henry Wilder Brown
A. B. Bryan, H. M. Buchner, T. I. Harkins

Kenneth S. Cohick
Joseph C. Waterman, Harry L. Thomsen, H. R. Thornburgh

Elihu Henry Cooley
Joseph A. Sharpe, C. E. Buffum, A. C. Reid

Benjamin Darwin Farrow
Thos. R. Shugart, W. W. Newton, J. E. Jett

Virgil Glinden Feather
A. J. Hintze, W. H. Courtier, Vincent Miller

Frederick William Forward
A. J. Hintze, W. H. Courtier, Vincent Miller

Robert Nelson Harding
Louis A. Scholl, Jr., Geo. D. Mitchell, Jr., Roy L. Lay

John Harris
Craig Ferris, E. V. McCollum, Neal J. Smith

Reynolds Parnell Hearin
A. J. Hintze, W. H. Courtier, Vincent Miller

Arne Junger
Harry L. Thomsen, Joseph C. Waterman, H. R. Thornburgh

Charles Gibbs Langford
Edward L. DeLoach, Cyril B. Smith, Richard Williams

Charles Milroy McDaniel, Jr.
Edward L. DeLoach, Paul D. Crawford, Richard Williams

Robert James McGann
Dean Walling, Curtis H. Johnson, Jack M. Desmond

Robert Lewis Mims
F. Goldstone, L. K. Mower, M. O. Gibson

Herman Jarrett Owen
A. J. Hintze, Vincent Miller, W. H. Courtier

Charles Newton Page
Stanley W. Wilcox, H. C. Becker, J. E. Hawkins

John Frederick Partridge, Jr.
J. W. Hoover, Neal J. Smith, Ewin D. Gaby

William Riker Perret
C. A. Heiland (Article III-D-1 of the Society Constitution)

Kenneth Alexander Robertson
R. A. Peterson, B. W. Sorge, C. Hewitt Dix
Lewis Lemuel Shackelford, Jr.
J. W. Thomas, H. B. Peacock, J. E. Jonsson
Charles Sheldon Sharp
Hart Brown, J. Brian Eby, Joseph L. Adler
Samuel Kermit Van Steenbergh
John H. Wilson, W. Harlan Taylor, Robert H. Ray

ASSOCIATE

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J. W. Hoover, Neal J. Smith, H. B. Peacock
Robert Eric Ely
Dean Walling, J. M. Desmond (Article III-D-1 of the Society Constitution)
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George W. Robinson
Thos. R. Shugart, E. E. Wilson, W. W. Newton
Vivian Mills Smith
L. F. Athy, H. R. Prescott, E. J. Handley
Atlas H. Thompson
W. W. Newton, Frank H. Kennedy, T. R. Shugart

STUDENT

Philip Arthur Bloomer, Jr. (Univ. of Colo.)
W. Warren Longley
Everett Lawyer Campbell (Colo. School of Mines)
R. Maurice Tripp
Charles Colbeigh O'Boyle (Colo. School of Mines)
C. A. Heiland
Joseph Monroe Sullivan (Univ. of Colo.)
W. Warren Longley

TRANSFER TO ACTIVE

H. J. McCready, Jr.
J. Eugene Stones
Paul M. Tucker

THE THIRTEENTH ANNUAL MEETING OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS, HOTEL TEXAS, FORT WORTH, TEXAS, APRIL 7–9, 1943

The Thirteenth Annual Meeting of the Society of Exploration Geophysicists was held in Fort Worth, Texas, April 7–9, 1943, at the Hotel Texas, concurrently with the Annual Conventions of the American Association of Petroleum Geologists and the Society of Economic Paleontologists and Mineralogists. The registration for the three groups totaled 1,126, among which were the 188 members of the S.E.G. listed immediately after this resumé.

Society members convened for the Annual Business Meeting at 9:15 A.M. April 7th, with the first of the four technical sessions beginning immediately afterward, in the Crystal Ball Room on the 14th floor of the Hotel Texas. On the following day, the three organizations met jointly to hear the presidential addresses and other papers of mutual interest, again in the Crystal Ball Room, which was packed to overflowing. On Friday, April 9th, the three met separately in the morning for the presentation of technical papers not of joint interest. On this final morning of the meeting, not all Society members desirous of attending were able to crowd into the small Cactus Room with its limited seating capacity of about eighty. An excellent program of papers was arranged for those who could attend, however.

Friday afternoon the S.E.G., A.A.P.G., and S.E.P.M. reconvened in the Crystal Ball Room for the presentation of a symposium on "Favorable Areas for Wildcatting for War Needs."

The usual Society Luncheon was held Wednesday noon, April 7th, and drew a capacity crowd of 150 to the Den in the basement of the Hotel Texas. A highlight of the luncheon was Paul Weaver's discussion of "The Geophysicist as a Forecaster."

On Thursday evening, April 8th, from 9:00 to 11:30 P.M., the members of the three groups assembled at an informal smoker arranged by the Fort Worth Geological Society, which served as host for the annual meetings. Entertainment and refreshments were provided through donations obtained from various business firms.

John H. Wilson, Secretary-Treasurer of the Society in 1936–37, was in charge of arrangements for the Society meeting. The Society extends its grateful thanks to Mr. Wilson, to Mr. Spencer Normand, who aided him in making arrangements, and to the Fort Worth Chamber of Commerce for aid in handling the registration. For their aid in securing an excellent program of papers, the Society extends thanks to these members serving on the Program Committee: L. L. Nettleton, General Chairman; Andrew Gilmour; W. M. Rust, Jr.; Dart Wantland; and H. W. Washburn. The meeting would hardly have proved so successful without the combined efforts of those named above.

MEMBERS REGISTERED AT THE THIRTEENTH ANNUAL MEETING

Hal R. Adams	Charles B. Bazzoni	John L. Bible
Joseph L. Adler	A. F. Beck	R. N. Bills
E. D. Alcock	Roland F. Beers	F. L. Bishop
Michael Allon	Donald Beeth	L. W. Blau
Manuel Alvarez, Jr.	Roy F. Bennett	Frank W. Borman
A. J. Barthelmes	Thomas J. Bevan	W. T. Born

H. Hallock Brown
Hart Brown
A. B. Bryan
Montgomery R. Budd
C. E. Buffum
J. M. Bugbee
W. W. Butler
D. B. Campbell
F. F. Campbell
G. W. Carr
E. L. Caster
V. E. Child
Norman J. Christie
D. H. Clewell
R. Clare Coffin
D. M. Collingwood
Henry C. Cortes
Ira H. Cram
C. G. Dahm
R. H. Dana
Donald M. Davis
E. L. De Golyer
R. G. De Good
D. A. De Woody
Alexander Deussen
Arthur E. Dietert
C. H. Dix
D. R. Dobyns
John Doering
Chester Donnally
Norvel Douglas
Karl Dyk
J. Brian Eby
L. G. Ellis
T. P. Ellsworth
Haakon M. Evjen
H. M. Falkenhagen
Paul Farren
L. Y. Faust
John L. Ferguson
Barney Fisher
L. I. Freeman
J. F. Gallie
Derry Gardner
F. Goldstone
Cecil H. Green
W. G. Green
T. O. Hall
E. J. Handley
Willis W. Hardy
T. I. Harkins
Bruce H. Harlton
G. H. Harrington
Sidon Harris
J. E. Hawkins
C. A. Heiland
W. B. Heroy
H. F. Hieatt
A. J. Hintze
J. O. Hoard
John C. Hoffman
W. B. Hogg
W. E. Hollingsworth
Leo Horvitz
H. M. Houghton
Bela Hubbard
John F. Imle
Arland I. Innes
John S. Ivy
J. E. Jett
E. W. Johnson
M. C. Kelsey
W. B. Kendall, Jr.
J. L. Kezeler
Robert L. Kidd
H. Klaus
Frederic H. Lahee
Roy L. Lay
Paul H. Ledyard
John A. Legge
E. G. Leonardon
John A. Lester
O. C. Lester, Jr.
W. B. Lewis
J. B. Lovejoy
C. R. Lowe
J. B. Macelwane, S. J.
Phil F. Martyn
Tom D. Mayes
E. V. McCollum
John McCullagh, Jr.
Dupree McGrady
R. L. McLaren
Vincent Miller
J. P. Minton
Homer C. Moore
James L. Morris
P. E. Narvarte
Paul E. Nash
L. L. Nettleton
J. Neufeld
W. W. Newton
Odell C. Olson
W. S. Olson
J. E. Owen
J. H. Pernell
R. A. Peterson
O. S. Petty
E. A. Pielemeier
Sylvain J. Pirson
C. V. A. Pittman
J. C. Pollard
H. R. Prescott
W. R. Ransone
Robert H. Ray
Edward C. Reagor
F. F. Reynolds
Homer E. Roberts
F. W. Rolshausen
Frederick Romberg
E. E. Rosaire
H. W. Rose
C. M. Ross
W. M. Rust, Jr.
Henry Salvatori
C. W. Sanders
Raymond Lawrence Sargent
Dan M. Sawtelle
H. L. Schiflett
Henry Schoellhorn, III
Louis A. Scholl, Jr.
Wesley H. Seifert
A. L. Selig
W. A. Seyffert
Joseph A. Sharpe
T. R. Shugart
Ellis W. Shuler, Jr.
Daniel Silverman
D. C. Skeels
A. L. Smith
Leslie C. Spencer
Austin N. Stanton
Noel H. Stearn
Booth B. Strange

Everett F. Stratton
E. J. Stulken
Albert Taylor
Garvin L. Taylor
W. Harlan Taylor
J. W. Thomas
R. Maurice Tripp
R. F. Van Cleave
Stefan Von Croy
George E. Wagoner
Paul Weaver
John F. Weinzierl
S. S. West
G. H. Westby
M. B. Widess
Stanley W. Wilcox
Charles C. Williams
P. S. Williams
Richard Williams
E. E. Wilson
John H. Wilson
J. R. Winnek
L. H. Wise
Alexander Wolf
R. D. Wyckoff
Basil B. Zavoico

MINUTES OF THE ANNUAL BUSINESS MEETING OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS, HELD IN THE CRYSTAL BALL ROOM, HOTEL TEXAS, FORTH WORTH, TEXAS APRIL 7, 1943

The annual business meeting of the Society of Exploration Geophysicists was held in the Crystal Ball Room of the Hotel Texas, Fort Worth, Texas, April 7, 1943. The meeting was called to order at 9:15 A.M. by President F. Goldstone.

President Goldstone then called upon Secretary-Treasurer T. I. Harkins to read the minutes of the previous meeting, held April 24, 1942, in Room D of the Cosmopolitan Hotel, Denver, Colorado. As the first of the new business to be considered, the Secretary-Treasurer was also requested to present his Annual Report. A net excess of income over expense of $2,072.17 was shown for the year ending December 31, 1942.

Editor Joseph A. Sharpe then presented a brief report covering the year's editorial activities. He advised the assembled Society members that Journal income had again exceeded expense for the year. He also stated that he was endeavoring to keep up the standards set by geophysical papers presented in GEOPHYSICS in previous years, and requested that additional papers be sent in by the membership.

A brief report was read on the War Efforts Advisory Committee's activities for the year. Following this, President Goldstone announced the results of the annual election of officers, as follows:

President, R. D. WYCKOFF
Vice-President, W. M. RUST, JR.
Secretary-Treasurer, HART BROWN

There being no further business, upon motion being duly made and passed, the meeting was adjourned.

Respectfully submitted,
T. I. HARKINS

PAPERS PRESENTED OR READ BY TITLE AT THE TECHNICAL SESSIONS OF THE THIRTEENTH ANNUAL MEETING OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS, HOTEL TEXAS, FORT WORTH, TEXAS, APRIL 7–9, 1943

The following papers were presented or read by title at the technical sessions of the Society and will be presented in GEOPHYSICS this coming year:

1. FRANK GOLDSTONE, Shell Oil Co., Inc., Houston, Texas
   Maintaining an Adequate Level of Geophysical Prospecting
   Presidential address.

2. FREDERICK ROMBERG and VIRGIL E. BARNES, La Coste and Romberg, and Bureau of Economic Geology, Austin, Texas.
The Gravitational Anomaly of the Smoothingiron Granite Mass

Observations of the force of gravity are made in the neighborhood of the Smoothingiron granite mass in Llano County, Texas. A clearly defined gravitational anomaly is noticed. The gravity data, when considered in the light of the available geological information, permit certain conclusions to be drawn concerning the shape of the granite mass.

3. L. E. RANDALL, Consulting Geophysicist, Parkersburg, West Virginia
Geophysics in the Appalachian Area

This paper includes maps and charts showing area shot and number of seismic companies involved. The problems encountered in seismic surveying in this area are largely the result of surface or near-surface phenomena. One velocity problem is thought to be indigenous to the highly dissected erosional pattern where apparently there is a sporadic decay or loss of velocity in rock masses having an average elevation above the lowest contact between country rock and erosional fill. Average velocity iso-horizon contact maps are shown for one of these areas as well as the mapping on one such area before and after this velocity correction. Further attention is called to an apparent relation between these isovelocity discontinuities and faulting.

The writer has a very large volume of seismic records over an extensive area. Maps based on the accumulated records, reverse velocity profiles and well shots are included showing the regional areal distribution of these so-called iso-horizon velocity lines. The regional areal distribution of average record characteristics within a portion of the stratigraphic section related to the iso-horizon is used in conjunction with the regional iso-velocity lines to delineate the extension of a regional geologic trend. Subsequently available well information tends to substantiate the anomalous extension of the trend.

4. A. GARCIA ROJAS, Petroleos Mexicanos, Mexico, D. F.
Geophysical Exploration in Mexico—History and Future Possibilities

5. H. KLAUS, Klaus Exploration Co., Lubbock, Texas
Faulting in the Billings Field, Oklahoma, as Interpreted from Torsion Balance Data and from Subsequent Drilling

The results of an experimental torsion balance survey of the Billings Oilfield are shown by means of the conventional maps and of second derivative contour maps. The latter show good and consistent anomalies interpreted as faulting. The survey was made in July, 1937, some time after discovery of Ordovician production in the field, but long before faulting was established by drilling, and the results of the surveys were communicated to several oil companies interested in the area or in the method of analysis. In the meantime, faulting has been established by drilling, and the present subsurface interpretations are compared with the original torsion balance predictions with respect to such faulting. From the amount of agreement between the two sets of data, it is concluded that the torsion balance may still be used effectively for specialized purposes, particularly the investigation of faulting.

6. A. E. LOCKENVITZ, University of Texas, Austin, Texas
The Periodic Variations of the Gravitational Force

A commercial LaCoste-Romberg gravity meter has been operating as a self-record-

ing meter since last August. The recorded curves have been compared with those obtained from calculations on a rigid earth theory. The nature of the differences and some possible interpretations will be discussed.

7. T. A. ELKINS, Gulf Research and Development Co., Pittsburgh, Pennsylvania
Nomograms for Computing Tidal Gravity

It is possible, by the use of a nomogram devised by Dr. James B. Friauf (Journal of the Franklin Institute, volume 232, pages 151–174, 1941) for the solution of spherical triangles, to make simple nomograms for the computation of tidal gravity. Two types of such nomograms are explained and illustrated. The first is for computations at a fixed latitude on the earth; the second is for computations at a fixed point. With the second type, the computation of tidal gravity is reduced to a simple routine matter, especially if THE AMERICAN AIR ALMANAC is used as the source of the astronomical data needed. The accuracy of these nomograms is studied and a comparison is made of this new method with that recently devised by Dr. Adler (GEOPHYSICS, volume 7, pages 35–44, 1942).

8. JOSEPH L. ADLER, Independent Exploration Co., Houston, Texas
Geophysics in Exploration for Stratigraphic Oil Traps

Types of stratigraphic traps are classified and described. Importance of considering modifying structures in location of test wells is illustrated. Use of various types of seismic and gravimetric exploration in locating stratigraphic traps and modifying structures is analyzed, and new techniques are suggested as subjects for research.

9. R. M. TRIPP, Colorado School of Mines, Golden, Colorado
On a Geochemical Survey of the Fort Collins Anticline

An objective presentation of data derived from a hydrocarbon survey of a producing Rocky Mountain structure. The influence of secondary mineralization and radioactivity on soil-wax patterns is discussed briefly.

10. R. W. LAWRENCE, Hercules Powder Co., Wilmington, Delaware
Detonation in Explosives

11. PAUL WEAVER, Gulf Oil Corp., Houston, Texas
The Geophysicist as a Forecaster

Commercial geophysical operations are concerned with static conditions. The measurement of geophysical elements which change with time has possibilities of determining the course of certain geophysical changes and forecasting their future course. Consideration is given to such forecasting of volcanic, seismic and other events which may profoundly affect human life and property.

12. Conference: *Maintaining Geophysical Operations during the War*

Various prospecting and oil-company representatives' discussion of different phases of material, transportation and personnel problems arising from the war.

13. AUSTIN N. STANTON and V. N. JAMES, Dept. of Electrical Engineering, Southern Methodist University, Dallas, Texas
Square Wave Testing of Seismograph Components

In testing amplifiers and other equipment components used in geophysical research

the inherent phase characteristics as well as the amplitude characteristics may be simultaneously analyzed by means of square waves. The wave shapes resulting from the application of square waves may readily be shown to correspond to transient responses of simple R, L, and C circuits. Performance tests on seismic equipment components will be demonstrated.

14. SYLVAIN J. PIRSON, Petroleum Geologist, Geophysicist, and Engineer, State College, Pennsylvania
A Two-Year Summary of Geodynamic Prospecting Results

The paper summarizes results obtained over the past 2 years with the new technique of gas-leakage measurements. Numerous examples of results are shown in an objective manner so that those who are interested in the survival and maintenance of the oil business according to past wildcatting practices may make their own appraisal of one of the new ideas which have been submitted as holding a potential solution to the problem of dwindling oil discoveries and reserves. The examples illustrated are grouped in two classes: predictions made on the probable outcome of drilling wells before their completion, and exploratory drilling surveys.

15. T. R. SHUGART, The Geotechnical Corp., Dallas, Texas
Frequency Discrimination in the Weathering

The various factors controlling the "character" of reflection seismograph records are so numerous and so complex that it is very difficult to isolate and investigate each of them experimentally. One of these factors is the frequency discrimination due to multiple reflections in the weathered layer. With a few simplifying assumptions this problem reduces to one already treated in the classical theory of acoustics. It is shown that for a given weathering depth the transmission is a periodic function of frequency. The ratio of the maximum to the minimum transmission is nearly equal to the square of the ratio of the specific acoustic impedance of the unweathered to that of the weathered layer. Graphs of transmission as a function of frequency are shown for various weathering thicknesses.

16. M. B. WIDESS, Stanolind Oil and Gas Co., Tulsa, Oklahoma
Multiple Branches in Seismic Reflection Time Surfaces

When for a given shot-point and receptor more than one reflection is recorded from a given reflecting bed, the corresponding reflection-time surface may be said to be multiple branched. Although multiple branches are difficult to evaluate, serious errors in mapping may result when their presence is overlooked. A method is therefore proposed for the interpretation of field data to account for this phenomenon. The conditions for branching and its properties are considered, showing that branches must occur in odd-numbered sets and in certain type forms, which are illustrated.

17. S. S. WEST, Stanolind Oil and Gas Co., Tulsa, Oklahoma
The Analysis of Gases by Scattering of Electrons

Methods are described for the analysis of mixtures of hydrocarbon gases by measurement of the probability of scattering of electrons as a function of energy of impinging electron, angle of scattering, or loss of energy during collision. By such means one can determine carbon-hydrogen ratio, proportions of single and multiple carbon-carbon bonds, and concentrations of gases in a mixture.

18. E. V. McCollum and Andrew Brown, Mott-Smith Corp., Houston, Texas
Use of the Gravity Meter in Establishment of Gravity Bench Marks

Data are presented showing comparisons between various gravity meters and networks of gravity meter bench marks. Methods of adjustment of networks for closure are suggested. Ties to pendulum stations of the U. S. Coast and Geodetic Survey and the Dominion Observatory of Canada afford a basis for the calibration of the gravity meters used and the evaluation of the gravity meter bench marks in terms of the world gravity network. Probable errors and accuracies are discussed.

19. J. A. Legge, Jr., United Geophysical Co., Pasadena, California
Determination of the Elevation Factor by the Method of Least Squares

A method is presented whereby the elevation factor based on the Bouguer equation may be determined by the method of least squares. The method may be applied to stations along a straight line or those haphazardly distributed over an area.

20. L. L. Nettleton and T. A. Elkins, Gulf Research and Development Co., Pittsburgh, Pennsylvania
Association of Magnetic and Density Contrasts with Igneous Rock Classifications

The frequent co-existence of strong magnetic and gravity anomalies directs attention to the properties of igneous rocks which may account for them. Density data are direct and unambiguous but magnetic data are much less certain. On the assumption that it is determined by disseminated magnetite, the susceptibility can be estimated from the proportion of magnetite in the rock. The possibility of estimating magnetite content from chemical analyses is examined and while not very satisfactory, it probably gives relative values of some merit. From published chemical analyses the magnetite content and probable intensity of magnetization are calculated for some 1,450 samples of igneous rocks, for which density values are also given. The values and resulting contrasts are analyzed statistically and tabulated for the C.I.P.W. and the Iddings method of classification. The contrasts, thus determined, are in reasonable agreement with expectations from the analysis of magnetometer and gravimeter surveys.

21. W. L. Russell, Stanolind Oil and Gas Company, Tulsa, Oklahoma
The Radioactivity of Sedimentary Rocks

Measurements of the total gamma ray intensity of 510 rock samples have been completed in order to improve the interpretation of radioactivity well logs. These determinations were made with a Geiger-Müller counter, and indicate the total radioactivity due to all elements. Since the intensity of radioactivity is related to the amount and nature of the organic matter present, the organic content of the sediments was also tested. The results of the investigation are summarized by figures showing the frequency distribution of radioactivity for different kinds of rock, and also the effect of varying proportions of different types of organic matter.

22. John J. Rupnik and J. A. Legge, Jr., United Geophysical Co., Pasadena, California
The Determination of the Velocity Function $V=V_0+az$ for Any Given Set of Time-Depth Data by Means of the Method of Least Squares

A method is described, and an example worked out, for making a best linear fit to

any given set of time-depth observations such as those obtained by well shooting. Using the formula

$$z = (V_0/a)(e^{at} - 1)$$

a least squares solution is developed and then applied to a hypothetical set of vertical times and depths.

23. E. D. ALCOCK, National Geophysical Co., Dallas, Texas
The Selection of Computational Methods for Seismic Paths

Due to the decrease in magnitude of structures being sought in seismic exploration, the selection of the most accurate method of computation assumes increasing significance. The various underlying assumptions and characteristics of several common computational methods are discussed and an analysis is made for a specific case.

24. S. S. WEST, Stanolind Oil and Gas Co., Tulsa, Oklahoma
On the Mutual Impedance of Collinear Grounded Wires

The formula of R. M. Foster for the mutual impedance of grounded wires lying on the surface of the earth has been evaluated for the case where the wires are grounded at points which are collinear and equally spaced upon the surface of a homogeneous earth. Curves are given showing mutual impedance and phase shift as functions of resistivity and frequency.

25. MARTIN J. GOULD, United States Navy Dept., Bureau of Ships, Washington, D. C.
(1) *Analysis of Various Proposed Explanations of the Ground Roll*

The quest for deeper seismic reflections has led to instrumental perfection of such a degree that future progress will depend upon an increased knowledge of the ground motion. As a step in this direction, the author analyzes various proposed explanations of the ground roll. Consideration of gravitational waves in a viscous medium of finite depth leads to velocities too small for ground roll wavelengths. The theory of Love waves on a visco-elastic layer overlying a visco-elastic substratum offers a possible explanation of the observed predominant ground roll frequencies, and a reduction of Love wave velocity because of the viscosity. The importance of Bateman's "secondary Rayleigh wave" cannot be known without the solution of the complex problem of the partition of energy at the source of the Rayleigh waves. An examination of seismic data on the velocity of the ground roll indicates that the observations are not necessarily inconsistent with the theory of dispersion of Rayleigh waves on a layered elastic medium, but that there may be other causes of the observed dispersion. In explaining certain unusual ground roll velocity variations near Fresno, California, the theory applies rather well, although the data are not very extensive. Analysis of three-component ground roll data leads to the required theoretical value of the ratio of major to minor axis of the retrograde particle motion ellipse, although there also exists an anomalous initial forward cycle of particle motion.

(2) *Note on Relation of Ground Roll from Explosion to Ground Roll from Ground Shaker*

An experimental investigation is described on the propagation of ground roll from an explosion and of surface waves from a ground shaker. The underground structure at the site of these observations was carefully determined from a shallow refraction profile and logging. Dispersion curves are presented in the form of phase velocity as a

function of L/H (wave length ÷ thickness of low velocity layer). The phase velocity of the ground roll is a linear function of L/H, over the range of L/H observed. The surface waves from the ground shaker give a different dispersion curve over a lower range of L/H. The two curves seem to come together at $L/H=8$. When the ground shaker curve is taken to be the extension of the ground roll curve to small L/H, the dispersion curve predicts the observed value of the group velocity of the ground roll.

26. W. B. Agocs, Dept. of Physics, Lehigh University, Bethlehem, Pennsylvania
A Method of Determining the Time Break on Deep Sea Records from the Water Sound Arrivals

A method is presented whereby through the use of the direct water wave first arrival, and the first and second reflections of sound from the surface of the sea, the following data may be obtained: (1) the ratio of the depth of the shot below the surface of the sea, to the lateral distance between the shot and detector; (2) the lateral distance between the shot and the detector at the bottom of the sea; and finally, (3) the time of detonation or the time break may be determined.

Calculation of the velocity of sound in sea water shows a linear variation of the velocity in definite zones with a rather abrupt change in velocity from zone to zone, as the depth is varied. Curvature due to refraction is found to be negligible.

Sample computations are given.

27. C. W. Horton, Underwater Sound Laboratory, Harvard University (formerly with Shell Oil Co.)
Secondary Arrivals in a Well Velocity Survey

Seismograms obtained in a well survey of the Shell-Longleaf Lumber Co. No. 1, Vernon Parish, Louisiana, showed well developed secondary arrivals which satisfied a velocity formula $V=(2000+0.27z)$ feet per second. If these arrivals are assumed to be transverse waves, a value of 0.43 for Poisson's ratio is obtained. On this same assumption, values of Young's modulus, modulus of rigidity, and Lamé's compression constant are computed for various depths. It is shown that the velocity of the secondary wave does not satisfy the equation developed by Lamb for thick-walled tube waves.

28. Wilbur H. Young, Jr., Empire Gas and Fuel Co., Wellsville, New York
Results of a Detailed Reflection Profile in New York

Of the many geoprospecting methods that have been attempted in the New York-Pennsylvania area the reflection seismograph has proven most successful. It has been used as a reconnaissance tool in mapping structure on the Tully limestone (Devonian) and more recently in the detailed profiling of fault zones either on the Tully at 4,000 feet or on lower horizons. Due to the vast amount of structural data available in the area from surface and shallow well data, the credit given seismograph in locating Oriskany sand (basal Devonian) gas production has been too much discounted. The question has often been proffered: "Where has seismograph work found structure that could not have been found by other means."

The author presents his answer to this question as one of the prime examples of production which would not have been found without geophysical means or the great expense of many dry holes drilled. The necessity of supplementing reconnaissance work with detail profiling and the need for close spacing of depth points in fault profiling is shown. Maps, cross sections and methods of profiling for an offset location in Inde-

pendence Township, Allegany County, New York, are presented with proof of structure determinations by subsequent drilling.

29. CHARLES W. OLIPHANT, Radio Research Lab., Harvard University, Cambridge, Massachusetts
Geochemical Data of the Lamont Prospect, Grant County, Oklahoma

30. Rev. DANIEL LINEHAN, S. J., Weston College, Weston, Massachusetts
Seismic Surveying in New England as an Aid to Geologic Interpretation

31. ALFRED WOLF, Geophysical Research Corp., Tulsa, Oklahoma
The Motion of a Weight on the Surface of an Elastic Earth.

The motion of a geophone case placed on the surface of an elastic solid does not follow faithfully the motion of the solid at high frequencies. This subject was discussed experimentally and theoretically in two recent papers.[1,2] In effect, a weight placed on the surface of an elastic solid constitutes a damped oscillating system. The elastic restoring forces are determined by the area of contact between the weight and the surface of the solid and by the elastic moduli of the solid. The mass of the solid also contributes to the inertia of the system. Equations are developed for these forces on the assumption that the wave length is long compared to the linear dimensions of the area of contact between the weight and the elastic solid. This leads to a determination of the natural frequency of oscillation and of the decrement of such a system.

[1] W. T. BORN and A. WOLF, "The Motion of a Geophone on the Surface of an Elastic Earth," presented at the Mid-year meeting of the Society of Exploration Geophysicists, November 20, 1937.

[2] HAROLD WASHBURN and HAROLD WILEY, *Geophysics*, Vol. VI, No. 2, p. 116, (April, 1941).

ANNUAL REPORT OF THE SECRETARY-TREASURER OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS

The annual increase in membership since the origin of the Society of Exploration Geophysicists is indicated in the following figures:

Year	*Honorary*	*Active*	*Associate*	*Student*	*Total*	*Increase*
1930	0	34	5	0	39	
1931	2	68	11	0	81	42
1932	2	83	11	0	96	15
1933	2	91	10	0	103	7
1934	2	141	23	0	166	63
1935	2	156	31	0	189	23
1936	4	195	34	0	233	44
1937	4	367	112	0	483	250
1938	4	510	158	0	672	189
1939	4	632	185	0	821	149
1940	4	700	188	0	892	71
1941	4	728	168	7	907	15
1942	4	760	166	11	941	34

The financial condition of the Society, as of December 31, 1942, is indicated in the following report, reproduced from the annual audit. In addition to the assets noted below, some 7,000 back numbers of GEOPHYSICS, bearing a minimum value (at $1 each, the cost to members) of $7,000, are on hand.

Balance Sheet—December 31, 1942

ASSETS

Current			
Cash			
In Banks		$ 6,730.16	
Accounts Receivable			
Advertising	$438.20		
Membership Dues	453.00		
Back Numbers	103.80		
Reprints	99.53		
Other	58.92	1,153.45	$ 7,883.61
Investment			
Farm and Home Savings and Loan Association Full Paid Shares Certificate		$ 5,000.00	
U. S. War Bonds (Series "G")		2,000.00	7,000.00
Office Equipment			
Cost		$ 101.17	
Less: Allowance for Depreciation		23.51	77.66
			$14,961.27

LIABILITIES

Current		
Accounts Payable		
For Expenses, etc.		$ 143.36
Deferred Income		
Prepaid Dues and Subscriptions		151.00
Surplus		
Balance January 1, 1942	$12,594.74	
Add		
Increase from Current Year Operations—Per Statement of Income and Expense	2,072.17	14,666.91
		$14,961.27

Income and Expense

INCOME

Membership Dues		$4,632.50		
Publications				
Advertising	$2,253.40			
Subscriptions	916.35			
Back Numbers	545.30			
Reprints	242.07	3,957.12		
Other Income				
Interest Received	$ 274.57			
Commissions on Publications	17.00	291.57	$8,881.19	
Less: Discounts to Colleges, etc. on Subscriptions and Back Numbers			99.92	$8,781.27

COSTS AND EXPENSES

Publication Costs			
GEOPHYSICS:			
Vol. VII, No. 1—138 pages...	$ 796.75		
No. 2—166 pages...	928.15		
No. 3—114 pages...	665.17		
No. 4—134 pages...	809.77	$3,199.84	
Reprints		224.68	$3,424.52
Expenses			
Salary—Business Manager		$1,200.00	
Commissions:			
Advertising:			
Business Manager	$ 188.35		
Agencies	290.56		
Subscriptions, etc.—Agencies	27.15	506.06	
Stationery and Office Supplies		392.00	
Postage and P.O. Box Rent		300.05	
Bad Debts		244.00	
Annual Meeting Expense:			
Traveling, etc.—Bus. Mgr.	$ 123.90		
Sound, Screens, Projectors	47.10		
Bus Trip—Denver and Golden	43.75		
Buttons, Signs, etc.	41.12		
Banquet—Net	28.50		
Stenographers	24.40		
	$ 308.77		
Less: 85 Bus Trip Tickets Sold	85.00	223.77	
Freight and Express		140.03	
Auditing		104.50	
Telephone and Telegraph		87.23	
Traveling Expense—Editor		27.70	
Binding, etc.		18.37	
Bond Premiums		15.00	
Society Card—A.A.P.G.		15.00	
Depreciation		9.56	
Bank Charges and Notary Fee		1.31	3,284.58
Excess of Income Over Costs and Expenses			$6,709.10
			$2,072.17

Respectfully submitted,
T. I. HARKINS, *Secretary-Treasurer*

PERSONAL ITEMS

CLAUDE WENDELL HORTON has joined the Underwater Sound Laboratory of Harvard University, Cambridge, Mass., as a Special Research Associate.

Former A/C JOSEPH G. HATHEWAY has earned his Wings in the Army Air Force and has been advanced to the rank of Lieutenant. His present address is 2451 Grove Street, Denver, Colo.

VICTOR J. PEZDEK and PAUL F. CLEMENT, of the Western Gulf Oil Co., have been transferred to Bakersfield, Calif., where they are located at 401 19th Street.

T. N. WALSH, recently with the General Geophysical Co., in Houston, has returned to Dallas, Texas, to accept employment in the Laboratory of Geophysical Service, Inc.

J. B. MEITZEN and JOE B. HUDSON, of the Humble Oil and Refining Co., have been transferred from Mobile, Ala., to 2316 American Bank Bldg., New Orleans, La.

L. J. SMITH, Seismologist with the Shell Oil Co., Inc., has been transferred to Centralia, Ill., where his postal address is Box 476. Mr. Smith was recently advanced from associate to active status in the Society.

M. M. SLOTNICK, who has been serving in the Navy Department's Naval Ordnance Laboratory and Bureau of Ordnance in Washington this past year, is returning to his former post with the Humble Oil and Refining Co. in Houston this month. His Houston address will be 4421 Roseneath Drive.

MANUEL ALVAREZ, JR., geologist and geophysicist formerly with Petroleos Mexicanos, has accepted a position with DeGolyer and MacNaughton, 1000 Continental Bldg., Dallas, Texas. His address in Mexico City is Nogal 52.

BERNARD G. HUBNER, Party Chief with the National Geophysical Co., is now located in Mineola, Texas, with the postal address P. O. Box 389.

JOHN J. RUPNIK is a Party Chief with the United Geophysical Co., P. O. Box 1527, Stockton, Calif.

T. R. SHUGART, Party Supervisor with the Geotechnical Corp., should be addressed at 1004 E. Broadway Street, Ft. Worth 3, Texas.

JACK M. DESMOND has left the employ of the Western Geophysical Co. to enter the armed services. He may be addressed at 4123 McClung, Los Angeles, Calif.

ANTON ERICKSON, formerly Seismograph Operator with the Continental Oil Co., has been serving as a Physicist in the Naval Ordnance Laboratory in Washington, D. C. since last August. He is located in Bldg. 184 in the Navy Yard in Washington.

L. C. PASLAY, also employed in the Naval Ordnance Laboratory, may be addressed at 3637 Austin Street, S.E., Washington, D. C.

SIDNEY SCHAFER has left the Tide Water Assoc. Oil Co. to accept employment with the Pan-American Production Co., Mellie Esperson Bldg., Houston, Texas.

LAWRENCE K. MORRIS has been transferred to South America, where he should be addressed c/o United Geophysical Co., Casilla #600, Punta Arenas, Magallanes, Chile. The same address serves for HENRY F. WISE.

D. S. HUGHES has left the Naval Ordnance Laboratory to return to his post with the Shell Oil Co., Inc. His address is 6645 Vanderbilt, Houston, Texas.

MAJOR B. B. HUNKAPILLER, formerly at Camp Blanding, is now serving as a member of the Observation Section Faculty, Field Artillery School, Ft. Sill, Okla.

RALPH H. HOWE is serving on a Petty Geophysical Engineering Co. seismic party for the Caribbean Petroleum Co., Aptdo. 19, Maracaibo, Venezuela.

Major DREXLER DANA should be addressed at Newton, Ill.

M. J. PELLILLO, Observer Supervisor with the National Geophysical Co., is located at 4727 University Boulevard, Dallas, Texas.

FRANCIS A. ROBERTS is with the Carter Oil Co., P. O. Box 30, Pauls Valley, Okla., as is G. E. SCHULTIS, newly-elected associate member.

Ir. J. J. H. JANSEN, Lieutenant with the Dutch Air Force, is located at 1827 Piedmont Street, Jackson, Miss.

GEORGE B. STONE, Test Engineer in the Mine Unit of the Naval Ordnance Laboratory, is currently doing research work in California. While away from Washington, he should be addressed at 5010 Caroline Boulevard, Houston, Texas.

C. H. MCALISTER, formerly with the Petty Geophysical Engineering Co., has accepted employment in the Naval Ordnance Laboratory as a Mechanical Engineer. His address in Washington is 53 Forrester, S.W.

Capt. JOHN M. GOLDEN has been transferred to Co. "B-3," A.F.R.T.C., Ft. Knox, Ky.

JAMES F. JOHNSON, formerly with the Continental Oil Co., is now a Computer with the Hoard Exploration Co., 1911 Esperson Building, Houston, Texas.

R. L. GEYER and O. B. JACKSON, of the Shell Oil Co., Inc., have been transferred to Box 957, Throckmorton, Texas.

A. M. MCMAHON is doing research work for the U. S. Government in Chicago, Ill. However, he is retaining his Houston, Texas, address—2501 Southmore Boulevard.

JOHN BAIRD is an Associate Engineer with the Navy Department's Bureau of Ordnance. His address is retained as 402 Pine, Boulder, Colo.

The North American Geophysical Co. has been formed, with HUGH C. SCHAEFFER as President, and with offices at 2505 Gulf Bldg., Houston, Texas, DALE H. MOOSE has advised the Society. Mr. Moose, formerly with the United Geophysical Co. (as was Mr. Schaeffer) is a Party Chief with the new company.

EDWARD D. LYNTON, formerly with the Standard Oil Co. of Calif. in Whittier, Calif., is now serving with the Board of Economic Warfare, Room 1300, Temporary "T" Bldg., 14th and Constitution, Washington, D. C.

J. W. THOMAS, JR., of the Stanolind Oil and Gas Co., has been transferred from Tyler to P. O. Box 307, Wills Point, Texas.

Capt. LEONARD F. UHRIG is with the Maintenance Bn., 5th A. D., APO 255, c/o Postmaster, Nashville, Tenn.

A. KLEIN HANEVELD, formerly with the Caribbean Petroleum Co., is now working with the Shell Co. of Ecuador, Ltd., Aptdo. 340, Quito, Ecuador, S. A.

CLINTON O. HURD, of the Cities Service Oil Co., has been transferred to 403 N. Walnut Street, Pauls Valley, Okla.

R. H. DANA, with the Stanolind Oil and Gas Co., has been transferred to P. O. Box 4188, Odessa, Texas, from Brownfield.

H. L. SCHIFLETT, of the Texas Co., recently reinstated as an active member of the Society, writes from Canada that he is spending a pleasant summer in Wetaskiwin, Alberta (P. O. Box 455), where the temperature hovers around 40°F. A scant four hours of darkness provides ample assurance that there will be no oversleeping on the crew.

PRESIDENT R. D. WYCKOFF announces the following roster of members of the WAR EFFORTS ADVISORY COMMITTEE for 1943–44; Chairman, Dr. B. B. Weatherby, Box 2040, Tulsa, Oklahoma; Mr. Frank Goldstone, Box 2099, Houston, Texas; Dr. A. B. Bryan, Box 801, Tulsa, Oklahoma.

THE HOUSTON GEOLOGICAL SOCIETY announces through its secretary, Hillard W. Carey, that the Society has recessed its meetings for the summer. The next meeting will be held on the mezzanine floor of the Texas State Hotel at 12 o'clock noon, September 2. Recent meetings have been addressed by Paul Weaver of the Gulf Oil Corporation on "The Geophysicist as a Forecaster"; by J. L. Mathieu of the Schlumberger Well Surveying Corporation on "The S. P. Dipmeter"; by Julius Fohs on "Some Notes on the Middle East"; and by Dr. Marcus A. Hanna of the Gulf Oil Corporation on "Some Theories on the Geology of Salt Domes."

Geophysicists of the Houston area are cordially invited to attend these meetings, which are held the first and third Thursdays of each month.